Hydro-Electric Power Commission of Ontario

Report of Progress on Queenston-Chippawa Power Development

by

R. S. LEA

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ON

Queenston-Chippawa Power Development

January 31st to April 9th, 1921

BY

R. S. LEA
CONSULTING ENGINEER

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REPORT

—OF—

R. D. JOHNSON

—OF—

R. D. JOHNSON & P. WAHLMAN

HYDRAULIC ENGINEERS

60 Wall Street

NEW YORK

—RE—

QUEENSTON-CHIPPAWA DEVELOPMENT

June 1920

MEMORANDUM

OF THE

PROBLEMS IN HYDRAULIC ENGINEERING

ENCOUNTERED BY THE

HYDRO-ELECTRIC POWER COMMISSION

Since the interest of the writer was first definitely enlisted in the proposed ideas and tentative plans looking toward a new water-power development near Queenston, so many difficult and interesting hydraulic problems have been encountered and solved, that it is thought worth while to rehearse them in outline, somewhat chronologically, as an index to the history of this branch of the engineering work, and possibly as a resumé for subsequent consultation with reference to similar undertakings.

The earlier considerations of the broad, comprehensive plan of development which eventually determined the location of the water intake and the power station with the intervening canal were fairly well crystallized, only, however, as to general outline, prior to the writer's direct interest in the enterprise, which began in April, 1915, and became officially recognized in September, 1916.

The Commission's engineers very evidently had in mind the adoption of a plan which would conform with the broad principles properly understood to be exemplified in a public undertaking, for the benefit of the people, and the ultimate conservation of water with respect to the power rendered available led to a more comprehensive layout than probably would have been attractive to private investors who usually prefer to skim the cream for present advantage and leave sour milk for posterity to subsist upon. Thus it was nothing short of the total available fall between Queenston and Chippawa was considered to be consistent with the above ideal. Having adopted this broad view of the matter, their next concern was to develop this complete fall in the most economical manner to secure the maximum of power for a minimum diversion of water out of its natural course so as not to mar the scenic beauty of Niagara Falls, and also to accomplish this result with the least expenditure of money consistent with economically durable construction. No effort has been spared to maintain the proper balances between far-seeing economy and immediate benefits, and the results so far attained indicate most able and competent management.

The consideration which led the engineers of the Commission to prefer a canal to a tunnel are probably more numerous than those which can be now called to mind, but some of them appeared later on, during a careful re-consideration of this question in which the writer largely participated. This careful overhauling and re-investigation was begun early in 1916 and was continued for more than a year, concluding with an endorsement by the engineers of their original choice of a canal.

The comparative merits of these two types of water conduits were weighed in every aspect, more thoroughly and carefully than is almost ever possible in connection with undertakings of less magnitude, and this generalization includes, probably, all other prior developments. It was found, amongst a multitude of other things, that it was not practically feasible to secure as low a value of head loss in a tunnel as could reasonably be obtained by means of a canal, although the over-all economy of the two methods was not clearly directed to either course of procedure when the value of the difference in head-loss was capitalized as lost power and added to the estimated cost of the tunnel. Nevertheless, it was recognized that, apart from any apparent balance in the comparative economies, power lost in friction is for ever gone and might reasonably prove, in the long run, to have a much higher value than at present foreseen; but the main consideration which seemed to favor a canal, at least in the opinion of the writer, was that, during these studies, the Commission found it possible to provide much more capacity in the canal than was at first contemplated, and as this enlargement of the canal cut could be made, for the most part, merely by deepening the channel without materially adding to the already enormous overburden of earth which had to be stripped from the rock, in any event, the relative merits of an open cut and tunnel began increasingly to favor the former; so that, although the writer himself initially favored a tunnel for a capacity of 6,000 to 10,000 sec. ft., yet he is not inclined to hold this position with the capacity materially increased as now contemplated. In other words, the choice based upon generalities is not so clearly pointed out as to make it independent of the quantity of water to be handled, and when this quantity is increased by merely deepening the rock cut, the advantage of a canal becomes more and more apparent: in this way it is possible to make certain that no criticism of the present choice of water-way can be substantiated on any engineering basis.

In the fall of 1916 the writer began a systematic study of the hydraulic characteristics of the canal. This was carried on intermittently until the summer of 1918, and meantime the studies were being continuously pursued by the Commission's engineers. Many novel and interesting methods of analysis were developed for which opportunity had not been found in connection with smaller undertakings.

The value of a horse-power gained by additional excavation was determined to be considerably greater than the average horse-power produced by the whole development, and an accurate method was worked out, by which the horse-power lost in the canal could be determined with a minimum of labor for different amounts of excavation and for all stages of the river.

The old-fashioned methods of trial and error which were in vogue to approximate the curve of the water surface in a long canal, were so cumbersome and tedious as almost, if not quite, to preclude the possibility of performing the innumerable calculations necessary to determine the economical amount of rock to remove for a stated capacity of discharge, or the economical capacity for a given selected layout of the channel.

The method adopted for the determination of these surface curves, as explained in detail in the writer's report of February 1, 1917, and more particularly in the report of July 30, 1918, is a direct one, not involving trial values, and is so

rapidly accomplished that the complete transitory history of a series of surface curves was easily portrayed for a continuous alteration in some dimension of the canal cross-section.

By the use of graphical calculus it then became possible to determine, for an infinite number of different assumptions, the ratio of the cost of increasing the excavation an infinitesimal amount, to the corresponding infinitesimal amount of power gained thereby, and as this ratio represents the cost rate per horse-power at which additional power is being obtained by further excavation, and as this rate increases with the tentative size of the canal, it becomes quite easy to know, within certain limits, when it is time to stop enlarging the cuts to reduce the friction; that is, once the value of this conserved power is determined upon, as indicated in the writer's report of February 1st, 1917.

Perhaps the most surprising and least foreseen result of the water gradient studies was the effect upon the total loss of head produced by varying the slope of the bottom of the canal in such a way as to keep the excavation constant in amount; that is, to tilt the bottom line about its centre so as to vary the depth of the cut in opposite directions on either side of the centre of the rock section.

A multitude of studies of this nature showed, beyond question, that within rather wide limits the slope of the bottom had no material effect upon the total drop in the water surface, but affected only the shape of the profile of the surface, making it concave as viewed from above when the bottom was tipped up at the upper end and down at the lower, and convex for the opposite tilting, without materially altering the relative elevations of the water surface at the extremities. This, of course, within limits.

In one case a variation in the bottom slope of 3.5 feet in 10,000 had no appreciable effect upon the elevation of the water at the lower end of the canal.

Thus it was found possible to fix the slope of the rock bottom according to the best physical conditions for carrying out the work of excavation without particular refinement in its relation to the hydraulic features.

In a canal as long as this, the question of surges or discontinuous flow throughout the length of it, caused a good deal of concern until these phenomena were carefully studied. This was taken up in considerable detail by the writer in the summer of 1916, and has received much attention during the intervening period, up to the present time, by the Commission's engineers and himself, and it appears quite clear that enough information in this regard has been acquired so that safe operation will be provided in the Commission's plans.

An interesting fact in this connection is the prevalence of unsteady flow which will be the ordinary condition of operation; whereas, in a short canal, it is customary to assume that the same quantity of water is entering and discharging at the same time, this ideal state of affairs will almost never strictly obtain in the long Queenston-Chippawa canal, because the natural period of its surge vibration is so long that a wave once started will be sure to continue long enough to be accentuated or retarded many times by small changes of load before it would have time to die out of its own accord under the influence of friction: this is particularly true where the canal walls are smooth, as they will be when they are carefully lined with concrete as intended.

Therefore, it will be difficult to find an instant when the rate of flow which is being drawn in through the intake is precisely the same as that which is generating electricity at the power station; and the discrepancy, at times, will be very great.

One of the features of the canal layout which received especial consideration was the construction of the curves or bends at the points where the water suddenly changes its direction. A series of experiments conducted at the University of Toronto in the fall of 1918, following a report by the writer, decided the Commission's engineers to adopt a sharper bend than they had at first contemplated, but any elaborate preparation at these curves, such as guiding vanes or other artificial direction of the stream lines did not appear to be warranted in view of the slight discrepancies discernible in the different constructions tested.

Of all the problems in connection with the canal, perhaps the most troublesome is the avoidance or disposal of ice, and this question has received an amount of attention proportionate to its importance. The Commission's engineers have had this constantly in mind for the past five years, and the writer has been somewhat in touch with it for a like period; but more particularly in connection with his reports of July, 1918 and January, 1919.

The methods which have been adopted possess the double virtue of precluding the possibility of taking into the mouth of the canal any surface ice and also of effectually removing any which may form on the canal itself. The latter idea was presented to the writer by the Commission's engineers in the spring of 1918, and after undergoing some modification, was finally adopted. It consists of a horizontal diaphragm or skimmer embracing the whole width of the canal, the lip of it adjustable to the various water stages; this diaphragm skims off the top layer of ice-laden water and diverts it into a special discharge tunnel entirely separated from the canal itself.

The hydraulic proportions are carefully designed to provide an acceleration of the natural surface velocity as the water there comes into contact with the edge of the skimmer, so that the waste water and ice, on top of it, begin to move faster than the water below it, as soon as the separation is effected. Thus, ice approaching the edge has no tendency to be sucked down underneath the skimmer where the undisturbed, ice-free water continues on its way toward the power station.

As previously indicated, this skimmer is intended only to remove ice which may be formed on the surface of the canal itself, between the intake and the skimmer. Beyond the skimmer lies the Forebay, and any ice formed on its surface will be taken care of in an ordinary sluice at one end of the screen house.

The floes of river ice will be effectively excluded from the canal by means of a novel intake which permits a complete separation of the ice-laden water from that drawn into the mouth of the canal. The final design of this is the result of the co-operation of the Commission's engineers with the office of the writer in adapting an idea conceived by Mr. Wahlman in his South American experience.

The essential characteristic of this intake is the ability to draw the water evenly from the bottom of the river through continuous slots, into tubes arranged somewhat like the fingers of a hand, with the wrist representing the entrance to the canal.

Although the general conception is somewhat obvious and simple, it has never been used before in this country, to the writer's knowledge, partly, perhaps, because its apparent simplicity is very misleading. That is to say, it is far easier to conceive the water to be drawn into these fingers, evenly and in proportion to the water flowing in the river at all points, than it is to so proportion the hydraulic dimensions as actually to secure this ideal result. In fact, a completely new

theory of the flow of water had to be evolved, developed and demonstrated by costly experimental determinations, before the Commission felt justified in preparing plans for the intake. This work covered a period of two years' time, or more, and received the attention of outside consulting advisors besides that of Mr. Wahlman and the writer, as well, of course, as the constant study of the Commission's engineers.

The services of a professor of hydraulics of the University of Toronto were engaged to lay out an exact miniature reproduction of the Niagara River at Hog Island. This was done with great attention to detail, in the Dufferin Island channel of the Niagara Falls Park, and the result was a very satisfactory working model of the river and the adjoining Chippawa Creek to a scale of one to twenty, with the water discharges in the ratio of one to the square root of twenty, of the actual river flow.

On this artificial "site" five different types of intake were successively constructed and their behaviour carefully noted by measuring all the important gradients, discharges and velocities. The ice conditions were reproduced by means of floating bottles properly weighted by the proportion of water contained in them and by blocks of wood of proper density.

The model constructed according to the plan submitted by Johnson & Wahlman proved to behave exactly as the accepted theories anticipated, and this idea was, accordingly, adopted by the Commission as the best one up to date.

The theory relating to the flow of water in this intake is set forth in the writer's report under date of March 1st, 1920, although the general outline was presented in a report dated January 31st, 1919.

Amongst the features which mark real progress on the hydraulic side of the water-power art, as will be demonstrated in the Queenston-Chippawa Development, may be mentioned the draft tubes, the Turbines themselves, the controlling Valves, the Sluice for trash removal in the screen-house, the Control Gate in the canal, etc. All of these features will represent the last word in their respective fields as determined by the close association of the Commission's engineers, not only with the engineers of all the most recent water-power developments in the United States and Canada, but also with the staffs of many of the most forward-looking manufacturers of hydraulic apparatus, some of whom regularly employ consulting engineers of high standing, and continually carry on experimental work to keep themselves abreast of the times.

The discharge or draft tubes leading from the turbines will be of the very largest type, and will be modelled according to the results of a long series of experiments conducted at Niagara Falls, N.Y., and at Philadelphia. They will have straight, vertical axes, avoiding the losses incidental to the ordinary bent tubes, and will certainly take their place in the vanguard of advancing attainment in this field of endeavour.

The turbines themselves will be unsurpassed in all particulars by any similar apparatus in the world, combining many novel features of safety and convenience of operation with the utmost conservation of the energy in the water which feeds them.

The valves which cut off the water when repairs to the turbines are necessary will be of the most approved "Johnson" type, now recognized to be indispensable where the utmost safety and convenience of operation are desired. They will be fitted with several important improvements which have not previously appeared in earlier installations.

The means for unwatering the rock section of the canal is unusual in the respect that no permanent obstruction to the flow is introduced in connection with the gate which shuts off the water. It has been found feasible and safe to provide one single gate, large enough to span the entire 48 feet width of channel, without resorting to a constriction of the water passage at that point, either by narrowing the channel or by inserting piers, as is often done to cut down the width of the gates. A single gate designed to sustain a water pressure of 1,200 tons is a bold conception, but a careful study has revealed no troublesome obstacles either in its construction or operation, and the wonder seems to be that larger gates for such purposes have not been more frequently adopted. The cost is very little, if any, greater than that of multiple gates, and the freedom from objectionable eddies which would otherwise trail along the water-way for a long distance beyond the point of obstruction, not only presents a much better appearance, but can be shown to have a real value in the saving of energy.

Although it is a fact that while oversights in engineering on a work of this magnitude would be correspondingly costly, yet the enormity itself, of the undertaking, has attracted the interested attention of a great number of able engineers, apart from the worthy staff of the Commission, and it may therefore safely be predicted that no advanced ideas in the water-power art will be overlooked, and no errors of serious or permanent consequence can be made without discovery in time to rectify them.

The Queenston-Chippawa Development, when completed, bids fair to furnish the best of material for the instruction and guidance of the students of hydraulic engineering, as a magnificent exposition of the art, and a display of the utmost proficiency of its period, in all particulars.

(Sgd.) R. D. JOHNSON.

REPORT

ON

CHIPPAWA HYDRO-ELECTRIC PROJECT

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

LETTER OF TRANSMITTAL

to

SIR ADAM BECK

Chairman

HUGH L. COOPER & CO.

Consulting Engineers

101 Park Avenue

New York City

August 7, 1920

New York, N.Y.,
August 7, 1920.

Sir Adam Beck, Chairman,
Hydro-Electric Power Commission of Ontario,
Toronto, Ontario, Canada.

Sir:—

On April 22, 1920, your Commission gave us instructions calling for a general report from us on your Chippawa Hydro-Electric Power Project. Verbal instructions from you have emphasized the desire of the Commission that our examinations should be thorough and comprehensive and thus enable us to submit findings of a definite character. Our work since May 5th, 1920, has been continuous, with as many engineers and accountants as we believe necessary for the faithful discharge of the duty you have imposed.

We find the general plan of an open canal system as located on the plans submitted to us by your engineers, to be the best that could have been adopted when the history of your project is fully understood. The Project, as a whole, is the most ambitious hydro-electric undertaking yet devised by engineers on this continent or elsewhere.

We believe the expenditures which you will be required to make on this project will be justified by the beneficial results which will accrue to the industrial life of the Province of Ontario.

The report of our findings and recommendations will consist of the following digest and summary, and a complete supplementary report, which will follow later, giving details of all our investigations and reasons for our recommendations.

1. This project as originally planned called for the use of 6,500 c.f.s., and was later increased to 15,000 c.f.s. We are of the opinion that this quantity of water should be increased to 20,000 c.f.s. Owing to the type of water transmission adopted by your engineers, this increase in the use of water is possible without any appreciable loss of money for work thus far completed.

2. The question of the availability of 20,000 c.f.s. is of first importance. The United States Government engineers are about to recommend to the American Federal Congress that 80,000 c.f.s. be diverted from the Niagara River for power purposes; 40,000 c.f.s. by Canada, and 40,000 c.f.s. by the United States.

The inefficient use of water at Niagara Falls has become a serious problem. The American Government is requiring the abandonment of one inefficient plant on the American side. The Commission may ultimately decide that the best interest of the public will be served by an arrangement with the Canadian Niagara Power Company for the use by the Chippawa plant of the 8,225 c.f.s. which are now being inefficiently used by the Canadian Niagara Power Company.

The unused quantity of water under the present Treaty allotment amounts to 6,610 c.f.s. The balance needed to complete the recommended 20,000 c.f.s., namely, 1,165 c.f.s. could be taken from the Ontario Power Company.

3. The normal elevation of the water surface at the point of diversion from the Niagara River, as adopted by your engineers, is 560.50.

Owing to the imminence of considerable increased diversion from the Niagara River for power purposes above those now permissible, we are of the opinion that the elevation of the water surface at the point of diversion should be taken as El. 558.00. We find that with 15,000 c.f.s. in commission with normal tail water, the minimum operating head will be 292 feet, and with 20,000 c.f.s. this head will be 299 feet.

4. The term "Horsepower" as used in this report, will mean an electrical horsepower delivered to the high tension lines going out from the generator station.

In estimating the quantity of horsepower that will be produced by different plans discussed, we have used the following coefficients:

Kutter's formula has been used for all water transmission determinations where 0.04 has been applied for canal sections in earth, and .014 for concrete-lined canal sections. We have made a total deduction of 7½% of the quantity of water entering the intake, to be used for flushing purposes during the winter season and to compensate for probable wind losses. The general report will contain our reasons for the use of the foregoing coefficients.

5. We recommend certain changes in your present adopted plans, as follows:

6. Intake.—We believe the design of intake adopted by your engineers should be abandoned, and a fixed masonry boom substituted therefor. We find the plan adopted by your engineers will cost $3,359,093.80. The cost of the substitute fixed boom protection will be $581,640.00.

We are certain the intake proposed by your engineers would be a disappointment if built, for reasons which will appear in our general report. The saving resulting from this recommendation amounts to $2,777,453.80, entirely. The fixed boom arrangement proposed follows successful engineering precedents at the Toronto Power Company plant, and at Keokuk, Iowa, and other plants designed by us.

7. Welland River Section.—We recommend that all of the Welland River Section, except that part near Station 244-00, be excavated with slopes 1 : 2, and the excavation be accomplished by the use of a suction dredge instead of the dipper dredge and cableway now being used.

8. Canal Section.—We recommend that the canal section between stations 0-00 and 45-00 be excavated to slopes 1 : 2 by use of the suction dredge method. If recommendations in paragraphs 7 and 8 are adopted, we estimate the following savings will be effected:

9. Suction Dredge Savings.—On the Welland River Section, $635,000.00 for 15,000 c.f.s., and $1,051,000.00 if 20,000 c.f.s. are used.

For the canal section, the saving will be $1,108,000.00 for 15,000 c.f.s., and $1,560,000.00 for 20,000 c.f.s.

Our investigations show that the material referred to in paragraph 9 can be taken out by a suction dredge in 75% of the time required by the methods now planned. In addition to the foregoing, the use of the suction dredge will re-

lease a considerable amount of your present equipment, thus further guaranteeing a sufficient amount of apparatus for the balance of your excavations.

The total saving due to the use of the suction dredge method will be $1,743,000.00 if 15,000 c.f.s. are developed, and $2,611,000.00 if 20,000 c.f.s. are developed.

10. Bridges.—We are of the opinion that material savings in the cost of uncompleted bridges can be made, but as this phase of the problem calls for considerable time for precise recommendations, no attempt at specific advice on this subject will be made here.

11. Whirlpool Section.—In the whirlpool section we find your engineers have used the best care possible for this difficult portion of the work, but in view of the unusual conditions that exist in this section, we recommend that a test be made of the stability of the whirlpool section by filling it with water before any concrete lining is placed on the slopes.

12. Skimming Works.—We recommend that near Station 444-0 there be constructed a complete skimming works for the effective removal of floating frazil and snow accumulating between the intake and this station. The cost of this necessary facility we estimate to be $499,350.00.

13. Forebay.—We believe that the forebay as now designed for either 15,000 or 20,000 c.f.s. requires modifications if satisfactory operating conditions are to be secured.

We recommend the construction and the experimental use of a concrete or wooden model to scale 1 : 20, of the forebay, and a study of the flow data thus produced. This data will prove the necessity for changes in the forebay design, and be a safe guide for the adoption of the most economical plans for this need.

In our estimate we have allowed $225,000 for this test, and for the resulting necessary alterations in the design of the forebay.

14. Screen House.—The general designs of screen house and penstock intakes are satisfactory. We will, however, recommend changes in the detail of the design in our general report.

15. Penstocks.—The general design of the penstocks is satisfactory. The question of expansion joints and other details will be referred to in the general report.

16. Power House Foundations.—During the period of our investigations we caused fifteen holes to be bored on the power house site. These disclosed the location and character of the rock which will serve as foundation for the power house. The foundation rock available is a red shale of acceptable quality for bearing purposes. These foundations, however, will be exposed to additional indeterminate and excessive lateral pressures from ice jams that occur in the river at and near the power house site.

We recommend that further borings be made in the river adjacent to the power house site, for the purpose of conclusively ascertaining the extent of the rock slopes. If further explorations show that the present power house location is in any danger from overhanging or insufficient slopes the present location should be moved back from the river to such a position as good judgment dictates.

We have included in our estimate $250,000.00 to cover the contingency of a possible change from the present location.

17. Turbines.—The hydraulic machinery under contract with Wm. Cramp and Sons is approved. Your contract requirements with the Wellman-Seaver-Morgan Company, while satisfactory as far as the guarantees are concerned, require special care with respect to a most thorough inspection of all of the work called for by this contract.

18. Valves.—The contract for the Johnson valves is in the main satisfactory, but special care should be devoted to inspection of details of design and shop work.

19. Electrical Apparatus.—The design of the electrical apparatus has not been studied. The statements of your engineers with respect to the same have been accepted as satisfactory.

20. Power House Substructure and Superstructure.—The general design of the power house indicates a stable structure, but no examination of the details has been possible for want of time. It seems to us that considerable savings can be effected by a re-design of the power house substructure.

No design of superstructure has been submitted, but we have estimated that a satisfactory design of superstructure can be provided at a cost not exceeding 40 cents per cubic foot, excluding cranes.

21. Organization.—We are of the opinion that all the engineering and business management connected with the design and construction of this plant with complete authority over every detail therein, should be located at Niagara Falls, Ontario, on the works.

We believe that the accounting system, as now installed, is too intricate, and that it should be greatly simplified and thus made to be of the maximum assistance to the Construction Department. We recommend that all accounts be audited by independent, certified public accountants every three months during the construction period. Our estimates of cost have necessarily been based, as far as tools and equipment are concerned, on figures supplied by your Accounting Department.

We recommend that a complete inventory be made at once of all tools, machinery and materials that have been bought for this work, and that this inventory be checked every ninety days, in the future, for the guidance of the Engineering and Accounting Departments.

We recommend that your Engineering and Construction Departments immediately prepare a work-time-schedule, setting forth specifically the monthly expected construction progress that is required for the final promised completion ready for commercial operation date.

Upon the adoption of such a schedule the same should be filed with the Commission, and the Construction Department should thereafter make a monthly report to the Commission setting forth clearly the relationship between actual achievement and the submitted scheduled forecast, for, in no other way can the Construction Management be held accountable.

We recommend that the Construction Department organize, maintain and test at least every ten days, an adequate system of fire protection wherever fire could interfere with construction progress, and that special vigilance be displayed in and about rock crushing and concrete mixing plants.

22. Labor.—Special recommendations with reference to the handling of labor will be submitted in the general report.

23. Cost.—The following paragraphs contain the discussion of the final costs and dates of completion for commercial operation, and the details for each case will be set forth in the final report.

Our examination of the accounts indicates a total expenditure of $19,936,370.86 up to May 1st, 1920, to which should be added $504,000.00 accrued interest from October 31st, 1919 to May 1st, 1920, making a total cost of the work to May 1st, 1920, of $20,440,000.00.

Case I.—If the work is completed according to your present plans using 15,000 c.f.s., we estimate the cost will be as follows:

(A)	Amount of H.P.	258,000
	Number of Units	5
	Total Cost	$66,423,418 00
	Cost per H.P.	$ 257 45
	Time of Completion	January 1, 1923
(B)	Amount of H.P.	389,000
	Number of Units	9
	Total Cost	$76,636,931 00
	Cost per H.P.	$ 197 00

Case II.—If 15,000 c.f.s. are used, and the recommendations in paragraphs 6 to 23 inclusive, are adopted, we estimate the cost will be as follows:

(A)	Amount of H.P.	258,000
	Number of Units	5
	Total Cost	$60,862,892 00
	Cost per H.P.	$ 235 90
	Time of Completion	January 1, 1923
(B)	Amount of H.P.	389,000
	Number of Units	9
	Total Cost	$72,216,635 00
	Cost per H.P.	$ 185 65

24. Available Water.—We are not advised as to how the Commission will procure the above 15,000 c.f.s. and the above costs per horsepower assume that the necessary 15,000 c.f.s. are obtained without expense.

We have suggested in paragraph 2, the acquisition of the Canadian Niagara Power Company by the Commission. Should this be accomplished, the necessary 15,000 c.f.s. would be available.

The arrangement we have in mind would provide for the furnishing to the Canadian Niagara Power Company of the amount of dependable power they now receive from the use of this 8,225 c.f.s., less an amount of power that equals the existing costs of operation and shutdowns due to ice.

The Canadian Niagara Power Company plant was unfortunately designed in the beginning as was generally believed at the time the plan was adopted, and has been continuously proven throughout its operating existence to date, and this fact should be taken actively into consideration when the amount of positive dependable power the Canadian Niagara Power Company would receive is being determined. Each winter season of its operation it has suffered marked interruption from ice trouble, and recently these interruptions have been as high as 40% of the total capacity.

If the foregoing arrangement is effected, the units in the Canadian Niagara Power Company plant thus made idle could be kept in reserve for future emergency use.

If the additional 8,225 c.f.s. are obtained as recommended above, and the compensation therefor is effected as suggested, then the amount of power mentioned in Cases I and II should be reduced by 80,000 H.P., thus producing costs per H.P. as follows:

CASE I—
For 9 Units .....$248 per H.P.

CASE II—
For 9 Units .....$233.71 per H.P.

25. CASE III.—If 20,000 c.f.s. are used and the recommendations mentinoed in paragraphs 6 to 23 inclusive, are adopted, we estimate the cost to be as follows:

(A) Amount of H.P. 311,000
Number of Units 6
Total Cost $71,988,626.00
Cost per H.P. 231.47
Time of Completion .....January 1, 1923

(B) Amount of H.P. 549,900
Number of Units 12
Total Cost $88,930,506 00
Cost per H.P. $162 00

If 20,000 c.f.s. are obtained in the manner recommended in paragraph 2, and the power compensated for as suggested in paragraph 24, then the total available power in Case III (B) will be reduced by that amount, or as follows:

(B) 549,000 H.P. minus 80,000 H.P. equals 469,000 H.P. Therefore, the unit cost becomes:

(B) 469,000 H.P. @.....$189.61 per H.P.

26. The foregoing figures show by way of justification of enlargement of the plant to 20,000 c.f.s., that you will secure 469,000 H.P. at a cost of $58.39 per H.P. less than by using 15,000 c.f.s. It will be observed that this great saving is accomplished by a full compensation to existing interests at Niagara Falls, and at the same time there is yielded for the benefit of the Ontario consumers their much needed power supply at a cost not to exceed 30% of the cost by steam, even if steam were available.

27. In conclusion we wish to extend to your entire organization our appreciation of the aid they have given us in the work preceding this report. Investigations and reports of this character are always an annoyance to any organization. Mr. Acres and all his men have provided our needs in a spirit of co-operation that was as unusual as it was welcome.

Yours very truly,

(Sgd.) HUGH L. COOPER & CO.

REPORT

ON

CHIPPAWA HYDRO-ELECTRIC PROJECT

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

COST ESTIMATES

HUGH L. COOPER & Co.

Consulting Engineers

101 Park Avenue

New York City

August 7th, 1920

EXPLANATORY.

This report covers six different cost estimates, each of which is to be identified by its special serial number.

Case I.—Estimate of cost of Project as designed by the Hydro-Electric Power Commission Engineers wherein Hugh L. Cooper & Company's quantities and unit prices have been applied.

QUANTITY OF WATER, 15,000 c. f. s.

Case II.—Estimate of cost of Project wherein Hugh L. Cooper & Company have introduced modifications in design, and applied their quantities and unit prices.

QUANTITY OF WATER, 15,000 c. f. s.

Case III.—Same as Case II using 20,000 c.f.s.

The letter "C" indicates the cost to complete to January 1, 1923. This date applies to 5 and 6 units only.

The numbers 5, 6, 9, and 12 indicate the number of units.

CONTINGENCIES.

Contingencies in this estimate are treated as follows:

Ten per cent. is added to the neat-line excavation quantities in earth for overcut.

Seven and one-half per cent. is added to all other quantities to provide for changes in design and contingencies.

The unit price applied to steel in the penstocks is $225.00 per ton. The tonnage includes an excess of 10% for the first 100 feet in elevation drop beginning at the forebay and 15% allowance for the remainder. These percentages are exclusive of the 7½% mentioned above.

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate I-C-5

(A) INTAKE

COFFERDAM				
Steel Sheet Piling	2,902½ tons	@	$125 00	$ 362,812 50
Fill	188,125 c. y.	@	1.20	225,750 00
Pumping				50,000 00
EXCAVATION				
Earth Excavation	380,550 c. y.	@	.65	247,357 50
Rock Excavation	21,500 c. y.	@	3.50	75,250 00
MASONRY				
Concrete, plain	50,525 c. y.	@	15.00	757,875 00
Concrete, reinforced	34,400 c. y.	@	40.00	1,376,000 00
STRUCTURAL STEEL				
Gate Beams	223,063 lbs.	@	.10	22,306 30
MISCELLANEOUS				
C. I. Spacers	118,250 lbs.	@	.15	17,737 50
Gantry Crane				15,000 00
2 Lock Gates & Oper. Mach.				100,000 00
Fill, earth	169,850 c. y.	@	.60	101,910 00
Rip Rap	7,095 c. y.	@	1.00	7,095 00
Total				$3,359,093 80

(B) WELLAND RIVER

Earth Excavation	2,541,073	c. y. @ $	.70	$1,778,751 10
Rip Rap	26,875	c. y. @	1.00	26,875 00
Concrete	1,613	c. y. @	16.00	25,808 00
Total				1,831,434 10

(C) POWER CANAL

CANAL EARTH SECTION

Earth Excavation	2,441,201	c. y. @ $	1.10	$ 2,685,321 10
Rock	77,736	c. y. @	3.50	[illegible]
Rock Lining	465,690	c. y. @	.15	69,853 50
Concrete	29,563	c. y. @	14.00	413,882 00
Total				$ 3,441,097 60

CONTROL WORKS

Rock Excavation	430	c. y. @	5.50	2,365 00
Concrete, reinforced	1,828	c. y. @	40.00	73,120 00
Gate, with Rollers Steel	240,800	lbs. @	.10	24,080 00
Gate Operating Machinery	107,500	lbs. @	.40	43,000 00
Bridge over Canal				25,000 00
Total				167,565 00

CANAL ROCK SECTION

Earth Excavation	3,011,036	c. y. @	1.10	3,312,139 60
Rock Excavation	2,939,365	c. y. @	3.50	10,287,777 50
Rock Fill	1,149,498	c. y. @	.15	172,424 70
Concrete in Walls	50,525	c. y. @	14.00	707,350 00
Concrete in Lining	285,090	c. y. @	14.00	3,991,260 00
Whirlpool	49,772	c. y. @	14.00	696,808 00
Anchor Rods, Steel	681,550	lbs. @	.20	136,310 00
Total				$19,304,069 80
Canal Earth Section				$ 3,441,097 60
Control Works				167,565 00
Canal Rock Section				19,304,069 80
Total Canal				$22,912,732 40

(D) FOREBAY

Earth Excavation				completed
Rock Excavation				completed
Concrete Lining	23,220	c. y. @	$14.00	$325,080 00
Concrete Walls	3,978	c. y. @	14.00	55,692 00
Anchor Rods, Steel	23,650	lbs. @	.20	4,730 00
Total				$385,502 00

(E) SCREEN HOUSE

SUBSTRUCTURE

Earth Excavation				completed
Rock Excavation				completed
Concrete, reinforced	26,810	c. y. @	$40.00	$1,072,400 00
Structural Steel in Racks	323,575	lbs. @	.075	24,268 13
Structural Steel in Gates	1,088,233	lbs. @	.075	81,617 48
Structural Steel in Checks	437,525	lbs. @	.10	43,752 50
Ice Chute Gate and Rig				25,000 00
Rock Fill	5,483	c. y. @	1.50	8,224 50
Earth Fill	5,052	c. y. @	3.00	15,156 00
Superstructure				237,405 00
Miscellaneous				75,000 00
				$1,582,823 61

(F) PENSTOCKS.

Tunnel Rock Excavation	6,450	c. y. @	$10.00	$ 64,500 00
Open Cut Rock Excavation	25,263	c. y. @	3.50	88,420 50
Concrete, plain	15,588	c. y. @	16.00	249,408 00

Concrete, reinforced	2,795	c. y. @	$40.00	111,800 00
Structural Steel	5,535,712	lbs. @	0.1125	622,767 60
Rip Rap, Wall	12,363	c. y. @	3.00	37,089 00
Total				$1,173,985 10

(G) POWER HOUSE.

COFFERDAM				
Concrete, plain	4,085	c. y. @	15.00	$ 61,275 00
Pumping				15,000 00
Removal Charges				45,956 00
SUBSTRUCTURE				
Rock Excavation	298,689	c. y. @	3.50	1,045,411 50
Concrete, reinforced	59,125	c. y. @	32.00	1,892,000 00
Tail Race Excavation	13,975	c. y. @	5.50	76,862 50
Superstructure				1,579,500 00
Miscellaneous				200,000 00
Emergency Fund				200,000 00
Total				$5,116,005 00

(H) HYDRAULIC EQUIPMENT.

Complete F. O. B. Queenston				$1,829,840 94
Storage, Transportation, erection	3,000	tons @	$60.00	180,000 00
Total				$2,009,840 94

(I) ELECTRICAL EQUIPMENT.

Complete in Place $4,752,160 00

(J) RIGHT OF WAY.

Acquired

(K) BRIDGES.

$1,534,023 82

SUMMARY

(A)	INTAKE	$ 3,359,093 80
(B)	WELLAND RIVER	1,831,434 10
(C)	POWER CANAL	22,912,732 40
(D)	FOREBAY	385,502 00
(E)	SCREEN HOUSE	1,582,823 61
(F)	PENSTOCKS	1,173,985 10
(G)	POWER HOUSE	5,116,005 00
(H)	HYDRAULIC EQUIPMENT	2,009,840 94
(I)	ELECTRICAL EQUIPMENT	4,752,160 00
(J)	RIGHT OF WAY	Completed
(K)	BRIDGES	1,534,023 82
Total		$44,657,600 77
ENGINEERING AND OVERHEAD 8 per cent		3,572,608 06
Total		$48,230,208 83
INTEREST CHARGES		
Interest at 6½% per annum compounded semi-annually		4,193,209 55
Total		$52,423,418 38
TOTAL DISBURSEMENTS		
To May 1st, 1920, plus interest compounded annually to January 1st, 1923		14,000,000 00
GRAND TOTAL		$66,423,418 38

(Signed) HUGH L. COOPER & CO.

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate I-C-9

(A) INTAKE

COFFERDAM.				
Steel Sheet Piling	2,902½ tons	@	$125.00	$ 362,812 50
Fill	188,125	c. y. @	1.20	225,750 00
Pumping				50,000 00
EXCAVATION				
Earth Excavation	380,550	c. y. @	.65	247,357 50
Rock Excavation	21,500	c. y. @	3.50	75,250 00
MASONRY				
Concrete, plain	50,525	c. y. @	15.00	757,875 00
Concrete, reinforced	34,400	c. y. @	40.00	1,376,000 00
STRUCTURAL STEEL				
Gate Beams	223,063	lbs. @	.10	22,306 30
MISCELLANEOUS				
C. I. Spacers	118,250	lbs. @	.15	17,737 50
Gantry Crane				15,000 00
2 Lock Gates and Operating Machine				100,000 00
Fill, Earth	169,850	c. y. @	.60	101,910 00
Rip Rap	7,095	c. y. @	1.00	7,095 00
Total				3,359,093 80

(B) WELLAND RIVER

Earth Excavation	2,541,073	c. y. @	.70	$1,778,751 10
Rip Rap	26,875	c. y. @	1.00	26,875 00
Concrete	1,613	c. y. @	16.00	25,808 00
Total				$1,831,434 10

(C) POWER CANAL

CANAL EARTH SECTION				
Earth Excavation	2,441,201	c. y. @	$1.10	2,685,321 10
Rock Excavation	77,726	c. y. @	3.50	272,041 00
Rock Lining	465,690	c. y. @	.15	69,853 50
Concrete Walls	29,563	c. y. @	14.00	413,882 00
Total				3,441,097 60
CONTROL WORKS				
Rock Excavation	430	c. y. @	5.50	2,365 00
Concrete, reinforced	1,828	c. y. @	40.00	73,120 00
Gate with Rollers, Steel	240,800	lbs. @	.10	24,080 00
Gate Operating Machinery	107,500	lbs. @	.40	43,000 00
Bridge over Canal				25,000 00
Total				167,565 00
CANAL ROCK SECTION				
Earth Excavation	3,011,036	c. y. @	1.10	3,312,139 60
Rock Excavation	2,939,365	c. y. @	3.50	10,287,777 50
Rock Fill	1,149,498	c. y. @	.15	172,424 70
Concrete in Walls	50,525	c. y. @	14.00	707,350 00
Concrete in Lining	285,090	c. y. @	14.00	3,991,260 00
Concrete in Whirlpool	49,772	c. y. @	14.00	696,808 00
Anchor Rods, Steel	681,550	lbs. @	.20	136,310 00
Total				19,304,069 80
Canal Earth Section				3,441,097 60
Control Works				167,565 00
Canal Rock Section				19,304,069 80
Total Canal				$22,912,732 40

(D) FOREBAY

Earth Excavation	Completed			
Rock Excavation	Completed			
Concrete Lining	23,220	c. y. @	$14.00	$325,080 00
Concrete Walls	3,978	c. y. @	14.00	55,692 00
Anchor Rods, Steel	23,650	lbs. @	.20	4,730 00
Total				$385,502 00

(E) SCREEN HOUSE

SUBSTRUCTURE				
Earth Excavation	Completed			
Rock Excavation	Completed			
Concrete, reinforced	26,810	c. y. @	$40.00	$1,072,400 00
Structural Steel in Racks	323,575	lbs. @	.075	24,268 13
Structural Steel in Gates	1,088,233	lbs. @	.075	81,617 48
Structural Steel in Checks	437,525	lbs. @	.10	43,752 50
Ice Chute and Rig				25,000 00
Rock Fill	5,483	c. y. @	1.50	8,224 50
Earth Fill	5,052	c. y. @	3.00	15,156 00
Superstructure				406,980 00
Miscellaneous				100,000 00
				$1,777,398 61

(F) PENSTOCKS

Tunnel Rock Excavation	11,126	c. y. @	$10.00	$ 111,260 00
Open Cut Rock Excavation	35,475	c. y. @	3.50	124,162 50
Concrete, plain	26,875	c. y. @	16.00	430,000 00
Concrete, reinforced	2,795	c. y. @	40.00	111,800 00
Structural Steel	9,226,187	lbs. @	.1125	1,037,946 04
Rip Rap Wall	19,135	c. y. @	3.00	57,405 00
				$1,872,573 54

(G) POWER HOUSE

COFFERDAM				
Concrete, plain	6,880	c. y. @	$15.00	$ 103,200 00
Pumping				25,000 00
Removal Charges				77,400 00
SUBSTRUCTURE				
Rock Excavation	375,014	c. y. @	3.50	1,312,549 00
Concrete, reinforced	99,975	c. y. @	32.00	3,199,200 00
Tail Race Excavation	23,650	c. y. @	5.50	130,075 00
Superstructure				2,673,000 00
Miscellaneous				250,000 00
Emergency Fund				250,000 00
Total				$8,020,424 00

(H) HYDRAULIC EQUIPMENT

Complete F.O.B. Queenston				$3,233,000 94
Storage, Transportation, Erection	5,400	tons @	$60.00	324,000 00
Total				$3,557,000 94

(I) ELECTRICAL EQUIPMENT

Complete in Place $8,417,360.00

(J) RIGHT OF WAY

Acquired

(K) BRIDGES

$1, 534,023 82

SUMMARY

(A)	INTAKE	$ 3,359,093 80
(B)	WELLAND RIVER	1,831,434 10
(C)	POWER CANAL	22,912,732 40
(D)	FOREBAY	385,502 00
(E)	SCREEN HOUSE	1,777,398 61
(F)	PENSTOCKS	1,872,573 54
(G)	POWER HOUSE	8,020,424 00
(H)	HYDRAULIC EQUIPMENT	3,557,000 94
(I)	ELECTRICAL EQUIPMENT	8,417,360 00
(J)	RIGHT OF WAY	Completed
(K)	BRIDGES	1,534,023 82
	Total	$53,667,543 21
	ENGINEERING AND OVERHEAD 8 per cent	4,293,403 45
	Total	$57,960,946 66
	INTEREST CHARGES	
	Interest at 6½% per annum compounded semi-annually	4,675,984 34
	Total	$62,636,931 00
	TOTAL DISBURSEMENTS	
	To May 1st, 1920, plus interest compounded annually to January 1st, 1923.	14,000,000 00
	GRAND TOTAL	$76,636,931 00

(Signed) HUGH L. COOPER & CO.

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate II-C-5

(A) INTAKE

EXCAVATION					
Earth for Piers	18,275	c. y.	@ $ .65		$ 11,878 75
Dredging	80,625	c. y.	@ .45		36,281 25
PIERS					
First Cost of Caissons					40,000 00
Installation of Caissons			each $3,000.00		111,000 00
Concrete, plain	7,955	c. y.	@ 15.00		119,325 00
Grillage	215 M	FBM	120.00		25,800 00
BOOMS					
Concrete, reinforced	5,237	c. y.	@ 40.00		209,480 00
PONTOONS					
Structural Steel	268,750	lbs.	@ .10		26,875 00
Painting					1,000 00
Total					$581,640 00

(B) WELLAND RIVER

Earth Excavation	1,373,601	c. y.	@ $ .45	$	618,120 45
Rip Rap	26,875	c. y.	@ 1.00		26,875 00
Total				$	644,995 45

(C) POWER CANAL

Canal Earth Section				
Earth Excavation				
Suction Dredge	1,034,979	c. y. @	$ .45	$ 465,740 55
Dipper	330,000	c. y. @	.80	264,000 00
Steam Shovel	696,523	c. y. @	1.10	766,175 30
Rock Excavation	79,016	c. y. @	3.50	276,556 00
Rock Lining	24,940	c. y. @	.15	3,741 00
Concrete	29,563	c. y. @	14.00	413,882 00
Total				$ 2,190,094 85
Control Works				
Rock Excavation	430	c. y. @	5.50	2,365 00
Concrete, Reinforced	1,828	c. y. @	40.00	73,120 00
Gate with Rollers, Steel	240,800	lbs. @	.10	24,080 00
Gate Operating Machinery	107,500	lbs. @	.40	43,000 00
Bridge over Canal				25,000 00
Total				167,565 00
Canal Rock Section				
Earth Excavation	3,011,036	c. y. @	1.10	3,312,139 60
Rock Excavation	2,939,365	c. y. @	3.50	10,287,777 50
Rock Fill	1,149,498	c. y. @	.15	172,424 70
Concrete in Walls	50,525	c. y. @	14.00	707,350 00
Concrete in Lining	285,090	c. y. @	14.00	3,991,260 00
Concrete in Whirlpool	54,610	c. y. @	14.00	764,540 00
Anchor Rods, Steel	681,550	lbs. @	.20	136,310 00
Total				$19,371,801 80
Ice Chute				
Open Cut Rock Excavation	64,500	c. y. @	5.50	354,750 00
Concrete, plain	1,290	c. y. @	20.00	25,800 00
Concrete, reinforced	1,720	c. y. @	40.00	68,800 00
Gates and Rigs				50,000 00
Total				$ 499,350 00
Testing of Whirlpool Section				
Concrete, plain	630	c. y. @	20.00	12,600 00
Earth Fill	21,500	c. y. @	.60	12,900 00
Pumping				10,000 00
Total				$ 35,500 00
Canal Earth Section				$2,190,094 85
Control Works				167,565 00
Canal Rock Section				19,371,801 80
Ice Chute				499,350 00
Testing of Whirlpool Section				35,500 00
Total Canal				$ 22,264,311 65

(D) FOREBAY

Earth Excavation				completed
Rock Excavation				completed
Concrete Lining	23,220	c. y. @	$14.00	$ 325,080 00
Concrete Walls	3,978	c. y. @	14.00	55,692 00
Anchor Rods, Steel	23,650	lbs @	.20	4,730 00
Alterations in Design				225,000 00
Total				$ 610,502 00

(E) SCREEN HOUSE

Substructure				
Earth Excavation				completed
Rock Excavation				completed
Concrete, reinforced	26,810	c. y. @	$40.00	$ 1,072,400 00
Structural Steel in Racks	323,575	lbs. @	.075	24,268 13
Structural Steel in Gates	1,088,233	lbs. @	.075	81,617 48

Cast Iron Gate Seats				10,000 00
Ice Chute Gate and Rig				25,000 00
Rock Fill	5,483	c. y. @	1.50	8,224 50
Earth Fill	5,052	c. y. @	3.00	15,156 00
Superstructure				237,405 00
Miscellaneous				75,000 00
Total				$1,549,071 11

(F) PENSTOCKS

Tunnel Rock Excavation	6,450	c. y. @	$10.00	$ 64,500 00
Open Cut Rock Excavation	25,263	c. y. @	3.50	88,420 50
Concrete, plain	15,588	c. y. @	16.00	249,408 00
Concrete, reinforced	2,795	c. y. @	40.00	111,800 00
Structural Steel	5,535,712	lbs. @	.1125	622,767 60
Rip Rap Wall	12,363	c. y. @	3.00	37,089 00
Total				$1,173,985 10

(G) POWER HOUSE

COFFERDAM				
Concrete, plain	4,085	c. y. @	$15.00	$ 61,275 00
Pumping				15,000 00
Removal Charges				45,956 00
SUBSTRUCTURE				
Rock Excavation	298,689	c. y. @	3.50	1,045,411 50
Concrete, reinforced	59,125	c. y. @	32.00	1,892,000 00
Tail Race Excavation	13,975	c. y. @	5.00	76,862 50
Superstructure				1,579,500 00
Miscellaneous				200,000 00
Emergency Fund				200,000 00
Total				$5,116,005 00

(H) HYDRAULIC EQUIPMENT.

Complete, F.O.B. Queenston				$ 1,829,840 94
Storage, Transportation, Erection	3,000	tons @	$60.00	180,000 00
Total				$2,009,840 94

(I) ELECTRICAL EQUIPMENT.

Complete in Place	$ 4,752,160 00

(J) RIGHT OF WAY.

Acquired

(K) BRIDGES

$1,534,023 82

SUMMARY.

(A) INTAKE	$ 581,640 00
(B) WELLAND RIVER	644,995 45
(C) POWER CANAL	22,264,311 65
(D) FOREBAY	610,502 00
(E) SCREEN HOUSE	1,549,071 11
(F) PENSTOCKS	1,173,985 10
(G) POWER HOUSE	5,116,005 00
(H) HYDRAULIC EQUIPMENT	2,009,840 94
(I) ELECTRICAL EQUIPMENT	4,752,160 00
(J) RIGHT OF WAY	Completed
(K) BRIDGES	1,534,023 82
Total	$40,236,535 07
ENGINEERING AND OVERHEAD 8 per cent.	3,218,922 81
Total	$43,455,457 88

INTEREST CHARGES	
Interest at 6½% per annum compounded semi-annually	3,407,434 24
Total	$46,862,892 12
TOTAL DISBURSEMENTS	
To May 1st, 1920, plus interest compounded annually to January 1st, 1923	14,000,000 00
GRAND TOTAL	$60,862,892 12

(Signed) HUGH L. COOPER & CO.

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate II-C-9

(A) INTAKE

EXCAVATION					
Earth for Piers	18,275	c. y. @	$ .65		$ 11,878 75
Dredging	80,625	c. y. @	.45		36,281 25
PIERS					
First Cost of Caissons					40,000 00
Installation of Caissons		each	3,000.00		111,000 00
Concrete, plain,	7,955	c. y. @	15.00		119,325 00
Grillage	215 M	FBM @	120.00		25,800 00
BOOMS					
Concrete, reinforced	5,237	c. y. @	40.00		209,480 00
PONTOONS					
Structural Steel	268,750	lbs. @	.10		26,875 00
Painting	.....	....	.....		1,000 00
Total					$ 581,640 00

(B) WELLAND RIVER

Earth Excavation	2,541,073	c. y. @	$ .45	1,143,482 85
Rip Rap	26,875	c. y. @	1.00	26,875 00
Total				$1,170,357 85

(C) POWER CANAL

CANAL EARTH SECTION				
Earth Excavation				
Suction Dredge	1,552,470	c. y. @	$ .45	698,611 50
Dipper	330,000	c. y. @	.80	264,000 00
Steam Shovel	696,523	c. y. @	1.10	766,175 30
Rock Excavation	79,016	c. y. @	3.50	266,556 00
Rock Lining	24,940	c. y. @	.15	3,741 00
Concrete	29,563	c. y. @	14.00	413,882 00
Total				$2,412,965 80
CONTROL WORKS				
Rock Excavation	430	c. y. @	5.50	2,365 00
Concrete, reinforced	1,828	c. y. @	40.00	73,120 00
Gate with Rollers, Steel	240,800	lbs. @	.10	24,080 00
Gate Operating Machinery	107,500	lbs. @	.40	43,000 00
Bridge over Canal				25,000 00
Total				$ 167,565 00

CANAL ROCK SECTION				
Earth Excavation	3,011,036	c. y @	1.10	3,312,139 60
Rock Excavation	2,939,365	c. y. @	3.50	10,287,777 50
Rock Fill	1,149,498	c. y. @	.15	172,424 70
Concrete in Walls	50,525	c. y. @	14.00	707,350 00
Concrete in Lining	285,090	c. y. @	14.00	3,991,260 00
Concrete in Whirlpool	54,610	c. y. @	14.00	764,540 00
Anchor Rods, Steel	681,550	lbs. @	.20	136,310 00
Total				$ 19,371,801 80
ICE CHUTE				
Open Cut Rock				
Excavation	64,500	c. y. @	5.50	354,750 00
Concrete, plain	1,290	c. y. @	20.00	25,800 00
Concrete, reinforced	1,720	c. y. @	40.00	68,800 00
Gates and Rigs				50,000 00
Total				$ 499,350 00
TESTING OF WHIRLPOOL SECTION				
Concrete plain	630	c. y. @	20.00	12,600 00
Earth fill	21,500	c. y. @	.60	12,900 00
Pumping				10,000 00
Total				$ 35,500 00
Canal Earth Section				2,412,965 80
Control Works				167,565 00
Canal Rock Section				19,371,801 80
Ice Chute				499,350 00
Testing of Whirlpool Section				35,500 00
Total Canal				$ 22,487,182 60

(D) FOREBAY

Earth Excavation			completed	
Concrete Lining	23,220	c. y. @	$14.00	$ 325,080 00
Concrete Walls	3,987	c. y. @	14.00	55,692 00
Anchor Rods, Steel	23,650	lbs. @	.20	4,730 00
Alterations in design				225,000 00
Total				$ 610,502 00

(E) SCREEN HOUSE

SUBSTRUCTURE				
Earth Excavation			completed	
Rock Excavation			completed	
Concrete reinforced	26,810	c. y. @	$40.00	$ 1,072,400 00
Structural Steel in Racks	323,575	lbs. @	.075	24,258 13
Structural Steel in Gates	1,088,233	lbs @	.075	81,617 48
Cast Iron Gate Seats				10,000 00
Ice Chute Gate and Rig				25,000 00
Rock Fill	5,483	c. y. @	1.50	8,224 50
Earth Fill	5,052	c. y. @	3.00	15,156 00
SUPERSTRUCTURE				406,980 00
MISCELLANEOUS				100,000 00
Total				$ 1,743,646 11

(F) PENSTOCKS

Tunnel Rock Excavation	11,126	c. y. @	$10.00	$ 111,260 00
Open Cut Rock Excavation	35,475	c. y. @	3.50	124,162 50
Concrete, plain	26,875	c. y. @	16.00	430,000 00
Concrete, reinforced	2,795	c. y. @	40.00	111,800 00
Structural Steel	9,226,187	lbs. @	.1125	1,037,946 04
Rip Rap Wall	19,135	c. y. @	3.00	57,405 00
Total				$ 1,872,573 54

(G) POWER HOUSE

COFFERDAM				
Concrete, plain	6,880	c. y. @	$15.00	$ 103,200 00
Pumping				25,000 00
Removal Charges				77,400 00
SUBSTRUCTURE				
Rock Excavation	375,014	c. y. @	3.50	1,312,549 00
Concrete, reinforced	99,975	c. y. @	32.00	3,199,200 00
Tail Race Excavation	23,650	c. y. @	5.50	130,075 00
SUPERSTRUCTURE				2,673,000 00
MISCELLANEOUS				250,000 00
EMERGENCY FUND				250,000 00
Total				$ 8,020,424 00

(H) HYDRAULIC EQUIPMENT

Complete F. O. B. Queenston				$ 3,233,000 94
Storage, Transportation, Erection	5,400	tons @	60.00	324,000 00
Total				$ 3,557,000 94

(I) ELECTRICAL EQUIPMENT

Complete in place 8,417,360 00

(J) RIGHT OF WAY

Acquired

(K) BRIDGES

$ 1,534,023 82

SUMMARY

(A)	INTAKE	$ 581,640 00
(B)	WELLAND RIVER	1,170,357 85
(C)	POWER CANAL	22,487,182 60
(D)	FOREBAY	610,502 00
(E)	SCREEN HOUSE	1,743,646 11
(F)	PENSTOCKS	1,872,573 54
(G)	POWER HOUSE	8,020,424 00
(H)	HYDRAULIC EQUIPMENT	3,557,000 94
(I)	ELECTRICAL EQUIPMENT	8,417,360 00
(J)	RIGHT OF WAY	Completed.
(K)	BRIDGES	1,534,023 82
Total		$ 49,994,710 86
ENGINEERING AND OVERHEAD 8 per cent		3,999,576 87
Total		$ 53,994,287 73
INTEREST CHARGES		
Interest at 6½% per annum compounded semi-annually		4,222,347 72
Total		$ 58,216,635 45
TOTAL DISBURSEMENTS		
To May 1st, 1920, plus interested compounded annually to January 1st, 1923		14,000,000 00
GRAND TOTAL		$72,216,635 45

(Signed) HUGH L. COOPER & CO.

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate III-C-6

(A) INTAKE

Excavation				
Earth for Piers	21,500	c. y. @	$ .65	$ 13,975 00
Dredging	104,275	c. y. @	.45	46,923 75
Piers				
First Cost of Caissons				40,000 00
Installation of Caissons		each	$3,000 00	111,000 00
Concrete, plain	8,600	c. y. @	15.00	129,000 00
Grillage	215 M	FBM	120.00	25,800 00
Booms				
Concrete, reinforced	5,237	c. y. @	40.00	209,480 00
Pontoons				
Structural Steel	268,750	lbs. @	.10	26,875 00
Painting				1,000 00
Total				$604,053 75

(B) WELLAND RIVER

Earth Excavation	2,804,881	c. y. @	$ .45	$1,262,196 45
Rip Rap	26,875	c. y. @	1.00	26,875 00
Total				$1,289,071 45

(C) POWER CANAL

Canal Earth Section				
Earth Excavation				
Suction Dredge	1,498,495	c. y. @	$ .45	$ 674,322 75
Dipper Dredge	330,000	c. y. @	.80	264,000 00
Steam Shovel	696,523	c. y. @	1.10	766,175 30
Rock Excavation	175,977	c. y. @	3.50	615,919 50
Rock Lining	27,413	c. y. @	.15	4,111 95
Concrete	32,250	c. y. @	14.00	451,500 00
Total				$ 2,776,029 50
Control Works				
Rock Excavation	457	c. y. @	5.50	2,513 50
Concrete, Reinforced	1,881	c. y. @	40.00	75,240 00
Gate with Rollers, Steel	322,500	lbs. @	.10	32,250 00
Gate Operating Machinery	139,750	lbs. @	.40	55,900 00
Bridge over Canal				25,000 00
Total				$ 190,903 50
Canal Rock Section				
Earth Excavation	3,011,035	c. y. @	1.10	3,312,138 50
Rock Excavation	130,494	c. y. @	5.50	717,717 00
Rock Excavation	3,442,258	c. y. @	3.50	12,047,903 00
Rock Fill	244,025	c. y. @	.15	36,603 75
Concrete in Walls	50,525	c. y. @	14.00	707,350 00
Concrete in Lining	307,235	c. y. @	14.00	4,301,290 00
Concrete in Whirlpool	61,598	c. y. @	14.00	862,372 00
Anchor Rods, steel	943,850	lbs. @	.20	188,770 00
Total				$22,174,144 25
Ice Chute				
Open Cut Rock Exc.	64,500	c. y. @	5.50	354,750 00
Concrete, plain	1,290	c. y. @	20.00	25,800 00

Concrete, reinforced	1,720	c. y. @	40.00	68,800 00
Gates and Rigs				50,000 00
Total				499,350 00
TESTING OF WHIRLPOOL SECTION				
Concrete, plain	788	c. y. @	20.00	15,760 00
Earth Fill	32,358	c. y. @	.60	19,414 80
Pumping				10,000 00
Total				$ 45,174 80
Canal Earth Section				$ 2,776,029 50
Control Works				190,903 50
Canal Rock Section				22,174,144 25
Ice Chute				499,350 00
Testing of Whirlpool Section				45,174 80
Total Canal				$25,685,602 05

(D) FOREBAY

Earth Excavation	29,025	c. y. @	$ 1.10	$ 31,927 50
Rock Excavation	239,725	c. y. @	3.50	839,037 50
Rock Excavation	145,125	c. y. @	5.50	798,187 50
Concrete Lining	34,905	c. y. @	14.00	488,670 00
Concrete Walls	4,300	c. y. @	14.00	60,200 00
Anchor Rods, Steel	33,863	lbs. @	.20	6,772 60
Alterations in Design				225,000 00
Total				$2,449,795 10

(E) SCREEN HOUSE

SUBSTRUCTURE				
Earth Excavation	3,600	c. y. @	$ 1.10	$ 3,960 00
Rock Excavation	14,050	c. y. @	3.50	49,175 00
Concrete, reinforced	38,808	c. y. @	40.00	1,552,320 00
Structural Steel in Racks	430,000	lbs. @	.075	32,250 00
Structural Steel in Gates	1,451,250	lbs. @	.075	108,843 75
Cast Iron Gate Seats				14,000 00
Ice Chute Gate and Rig				25,000 00
Rock Fill	7,848	c. y. @	1.50	11,772 00
Earth Fill	6,934	c. y. @	3.00	20,802 00
Superstructure				285,000 00
Miscellaneous				90,000 00
Total				$2,193,122 75

(F) PENSTOCKS

Tunnel Rock Excavation	7,633	c. y. @	$10.00	$ 76,330 00
Open Cut Rock Excavation	24,403	c. y. @	3.50	85,410 50
Concrete, plain	18,490	c. y. @	16.00	295,840 00
Concrete, reinforced	3,763	c. y. @	40.00	150,520 00
Structural Steel	6,353,250	lbs. @	.1125	714,740 63
Rip Rap	13,975	c. y. @	3.00	41,925 00
Total				$1,364,766 13

(G) POWER HOUSE

COFFERDAM				
Concrete, plain	5,160	c. y. @	$13.00	$ 77,400 00
Pumping				20,000 00
Removal Charges				58,050 00
SUBSTRUCTURE				
Rock Excavation	407,963	c. y. @	3.50	1,427,870 50
Concrete, reinforced	67,725	c. y. @	32.00	2,167,200 00
Tail Race Excavation	17,200	c. y. @	5.50	94,600 00

Superstructure	1,850,000 00
Miscellaneous	215,000 00
Emergency Fund	215,000 00
Total	.6,125,120 50

(H) HYDRAULIC EQUIPMENT

Complete F.O.B. Queenston	$2,218,040 00
Storage Transportation, Erection .... 3,600 tons @ $60.00	216,000 00
Total	$2,434,040 00

(I) ELECTRICAL EQUIPMENT

Complete in place	$5,668,460 00

(J) RIGHT OF WAY

Acquired	

(K) BRIDGES

$1,534,023 82

SUMMARY

(A)	INTAKE	$ 604,053 75
(B)	WELLAND RIVER	1,289,071 45
(C)	POWER CANAL	25,685,602 05
(D)	FOREBAY	2,449,795 10
(E)	SCREEN HOUSE	2,193,122 75
(F)	PENSTOCKS	1,364,766 13
(G)	POWER HOUSE	6,125,120 50
(H)	HYDRAULIC EQUIPMENT	2,434,040 00
(I)	ELECTRICAL EQUIPMENT	5,668,460 00
(J)	RIGHT OF WAY	Completed
(K)	BRIDGES	1,534,023 82
	Total	$49,348,055 55
ENGINEERING OND OVERHEAD 8 per cent.		3,947,844 44
	Total	$53,295,899 99
INTEREST CHARGES		
Interest at 6½% per annum compounded semi-annually		4,692,726 74
	Total	$57,988,626 73
TOTAL DISBURSEMENTS		
To May 1st, 1920, plus interest compounded annually to January 1st, 1923		14,000,000 00
GRAND TOTAL		$71,988,626 73

(Signed) HUGH L. COOPER & CO.

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate III-C-12

(A) INTAKE

EXCAVATION				
Earth for Piers	21,500	c. y. @	$0.65	$ 13,975 00
Dredging	104,275	c. y. @	.45	46,923 75

PIERS				
First Cost of Caissons				40,000 00
Installation of Caissons	each	@	3,000.00	111,000 00
Concrete, plain	8,600 c. y.	@	15.00	129,000 00
Grillage	215 M FBM	@	120.00	25,800 00
BOOMS				
Concrete, reinforced	5,237 c. y.	@	40.00	209,480 00
PONTOONS				
Structural Steel	268,750 lbs.	@	$ .10	26,875 00
Painting				1,000 00
Total				$ 604,053 75

(B) WELLAND RIVER.

Earth Excavation	4,207,323 c. y.	@	$ .45	$ 1,893,295 35
Rip Rap	26,875 c. y.	@	1.00	26,875 00
				$ 1,920,170 35

(C) POWER CANAL

CANAL EARTH SECTION				
Earth Excavation				
Suction Dredge	2,247,742 c. y.	@	$ .45	$ 1,011,483 90
Dipper Dredge	330,000 c. y.	@	.80	264,000 00
Steam Shovel	696,523 c. y.	@	1.10	766,175 30
Rock Excavation	175,977 c. y.	@	3.50	615,919 50
Rock Lining	27,413 c. y.	@	.15	4,111 95
Concrete	32,250 c. y.	@	14.00	451,500 00
Total				$ 3,113,190 65
CONTROL WORKS				
Rock Excavation	457 c. y.	@	5.50	2,513 50
Concrete, reinforced	1,881 c. y.	@	40.00	75,240 00
Gate with Rollers, Steel	322,500 lbs.	@	.10	32,250 00
Gate Operating Machinery	139,750 lbs.	@	.40	55,900 00
Bridge over Canal				25,000 00
Total				$ 190,903 30
CANAL ROCK SECTION—EARTH EXCAVATION				
Earth Excavation	3,011,035 c. y.	@	1.10	3,312,138 50
Rock Excavation	130,494 c. y.	@	5.50	717,717 00
Rock Excavation	3,442,258 c. y.	@	3.50	12,047,903 00
Rock Fill	244,025 c. y.	@	.15	36,603 75
Concrete in Walls	50,525 c. y.	@	14.00	707,350 00
Concrete in lining	307,235 c. y.	@	14.00	4,301,290 00
Concrete in Whirlpool	61,598 c. y.	@	14.00	862,372 00
Anchor Rods, Steel	943,850 lbs.	@	.20	188,770 00
Total				$22,174,144 25
ICE CHUTE				
Open Cut Rock Excavation	64,500 c. y.	@	5.15	354,750 00
Concrete, plain	1,290 c. y.	@	20.00	25,800 00
Concrete, reinforced	1,720 c. y.	@	40.00	68,800 00
Gates and Rigs				50,000 00
Total				$ 499,350 00
TESTING OF WHIRLPOOL SECTION				
Concrete, plain	788 c. y.	@	20.00	15,760 00
Earth Fill	32,358 c. y.	@	.60	19,414 80
Pumping				10,000 00
Total				$ 45,174 80
Canal Earth Section				$ 3,113,190 65
Control Works				190,903 50
Canal Rock Section				22,174,144 25

Ice Chute					499,350 00
Testing of Whirlpool Section					45,174 80
Total Canal					$26,022,763 20

(D) FOREBAY

Earth Excavation	29,025	c. y. @	$ 1.10		$ 31,927 50
Rock Excavation	239,725	c. y. @	3.50		839,037 50
Rock Excavation	145,125	c. y. @	5.50		798,187 50
Concrete Lining	34,905	c. y. @	14.00		488,670 00
Concrete Walls	4,300	c. y. @	14.00		60,200 00
Anchor Rods, Steel	33,863	lbs. @	.20		6,772 60
Alterations in Designs					225,000 00
Total					$ 2,449,795 10

(E) SCREEN HOUSE

SUBSTRUCTURE					
Earth Excavation	3,600	c. y. @	$ 1.10		$ 3,960 00
Rock Excavation	14,050	c. y. @	3.50		49,175 00
Concrete, Reinforced	38,808	c. y. @	40.00		1,552,320 00
Structural Steel in Racks	430,000	lbs. @	.075		32,250 00
Structural Steel in Gates	1,451,270	lbs. @	.075		108 843 75
Cast Iron Gate Seats					14,000 00
Ice Chute Gate and Rig					50,000 00
Rock Fill	7,898	c. y. @	1.50		11,772 00
Earth Fill	6,824	c. y. @	3.00		20,802 00
Superstructure					525,000 00
Miscellaneous					125,000 00
Total					$ 2,493,122 75

(F) PENSTOCKS.

Tunnel Rock Excavation	15,050	c. y. @	$10.00		$ 150,500 00
Open Cut Rock Excavation	47,945	c. y. @	3.50		167,807 50
Concrete, plain	36,335	c. y. @	16.00		581,360 00
Concrete, reinforced	3,763	c. y. @	40.00		150,520 00
Structural Steel	12,491,500	lbs. @	.1125		1,405,293 75
Rip Rap Wall	26,123	c. y. @	3.00		78,369 00
Total					$ 2,533,850 25

(G) POWER HOUSE

COFFERDAM					
Concrete, plain	8,708	c. y. @	$15.00		$ 130,620 00
Pumping					35,000 00
Removal Charges					97,965 00
SUBSTRUCTURE					
Rock Excavation	522,289	c. y. @	3.50		1,828,011 50
Concrete, reinforced	131,688	c. y. @	32.00		4,214,016 00
Tail Race Excavation	32,250	c. y. @	5.50		177,375 00
Superstructure					3,500,000 00
Miscellaneous					300,000 00
Emergency Fund					300,000 00
Total					$10,582,987 50

(H) HYDRAULIC EQUIPMENT

Complete, F.O.B. Queenston					$ 4,322,780 00
Storage, Transportation, Erection	7,200	tons @	$60.00		432,000 00
Total					$ 4,754,780 00

(I) ELECTRICAL EQUIPMENT.

Complete in Place	$11,166,260 00

(J) RIGHT OF WAY

Acquired.

(K) BRIDGES

$1,534,023 82

SUMMARY

(A)	INTAKE	$ 604,053 75
(B)	WELLAND RIVER	1,920,170 35
(C)	POWER CANAL	26,022,763 20
(D)	FOREBAY	2,449,795 10
(E)	SCREEN HOUSE	2,493,122 75
(F)	PENSTOCKS	2,533,850 25
(G)	POWER HOUSE	10,582,987 50
(H)	HYDRAULIC EQUIPMENT	4,754,780 00
(I)	ELECTRICAL EQUIPMENT	11,166,260 00
(J)	RIGHT OF WAY	Completed
(K)	BRIDGES	1,534,023 82
	Total	$64,061,806 72
	ENGINEERING AND OVERHEAD 8 per cent.	5,124,944 54
	Total	$69,186,751 26
	INTEREST CHARGES	
	Interest at 6½% per annum compounded semi-annually	5,743,755 42
	Total	$74,930,506 68
	TOTAL DISBURSEMENTS	
	To May 1st, 1920, plus interest compounded annually to January 1st, 1923	14,000,000 00
	GRAND TOTAL	88,930,506 68

FINAL REPORT

ON

CHIPPAWA HYDRO-ELECTRIC PROJECT

FOR

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

TORONTO, CANADA

HUGH L. COOPER & Co.
Consulting Engineers
101 Park Avenue
New York City

October 22, 1920

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[COPY]

New York, N.Y.,

HUGH L. COOPER & CO.

October 22, 1920.

SIR ADAM BECK, Chairman,

Hydro-Electric Power Commission of Ontario,

Toronto, Ontario, Canada.

Dear Sir:

1. In accordance with our arrangement with your Commission on April 26, 1920, we began actively the engineering examinations as described in our formal letter to your Mr. Acres dated May 1, 1920, a copy of which is attached hereto, marked Appendix C. The action of the Commission accepting our proposal was taken on April 27, 1920, according to a letter we have received from Chief Engineer Gaby, dated May 15, 1920. All of the work of investigation was completed on August 17, 1920 except for a very small amount of confirmatory investigation work which has taken place since August 17, 1920. During the time between April 26th and up to date, we have given your entire Chippawa Project our very best study.

2. PRELIMINARY REPORT.—On August 14, 1920, we filed with you our preliminary report dated August 7, 1920, a copy of which is attached hereto, marked Appendix A. The August 7th report was accompanied by cost estimates, a copy of which is attached hereto, marked Appendix B. The foregoing reports call for a final general report as follows:

3. SUBMITTED DRAWINGS.—We attach hereto as a part of our general report two sets of prints from our drawings Nos. 3438, 3439, 3440, 3441, to which reference should be made for understanding what follows. These blueprints will be hereinafter referred to as Appendix D.

4. SUBDIVISIONS OF PROJECT.—We have divided your project into the following subdivisions, the locations of which are indicated on Drawing 3438.

(*a*) INTAKE.—The point of diversion from the Niagara River is near the town of Chippawa at the mouth of the Welland River. At this point masonry structures are necessary for the effective diversion of the amount of water that is to be used for power purposes. This intake is required to effect the water diversion and at the same time relieve the water so diverted from all foreign matter that would interfere with the most efficient use of the same.

(*b*) WELLAND RIVER SECTION.—After the water is diverted from the Niagara River it is to flow up the Welland River for a distance of approximately 24,440 feet whence it is diverted into an artificial channel called the "earth section of canal." The section of the water transmission between the intake and the earth section of the canal will be referred to herein as the "Welland River Section."

(*c*) CANAL SECTION.—The artificial canal section between the Welland River and the forebay is approximately 45,300 feet long and is treated in two subdivisions:

1. The first or upper division designated as "earth section of canal," which is approximately 6,500 feet in length.

2. The second division from the control works to the forebay called the "rock section of the canal," which is approximately 39,000 feet long.

(*d*) Control Works.—Control works are planned to control the entrance to the rock section. These control works consist of one large steel gate and necessary masonry abutments.

(*e*) Forebay—Screen House—Penstocks and Power House.—The bottom end of the canal is enlarged into a forebay to permit of the installation of the penstocks that are to carry the water to the power house below. The top end of the penstocks terminate in abutments provided with screens and gates protecting and controlling water passing into the penstocks.

5. Water Transmission.—Water transmission as used in this report will refer to any or all of these structures that will be used in transmitting water from the intake to the tail race below the power house.

6. Personnel of the Investigation.—All of the field work was under the immediate charge of Mr. Dexter P. Cooper. We used a staff of engineers in the field. In addition to the field examinations under Mr. D. P. Cooper, our New York office engineers supplemented the work of the field organization. The field investigation had its headquarters on the works at Niagara Falls, Ontario. The results we have submitted to you previously and are submitting herewith have been arrived at after a study of the entire problem by all of the men in our organization qualified by experience to discuss and express opinions thereon.

7. Report of August 7th.—In this report no attempt will be made to restate any of the views or opinions submitted in our report dated August 7th, and the August 7th report together with the matter herewith submitted constitutes our final discharge of all the work we understand we are to perform for you under the existing contract.

8. Horsepower as Used Herein Defined.—The word "horsepower" as used herein will always refer to an electrical horsepower delivered to the high tension lines going out of the generating station. The foregoing definition requires that all friction and generating losses have been provided for and that the horsepower is net electrical horsepower deliverable to the transmission systems referred to above.

9. Data Regarding Losses.—In computing the discharging capacity of the various water transmissions the standard Kutter's formula has been used for the reason that engineering records supply a greater amount of dependable data for the use of this formula than would be found for the use of any other formula for this class of engineering computation. The successful use of any formula for water transmission depends entirely upon the intelligent selection of coefficients of friction, and after such selection, the determination of the results depends only upon correct mathematics, which mathematics are capable of absolute check. The coefficients of friction assumed are as follows:

For the Welland River Section	.04
For the earth section of the canal up to the control works	.04
For the concrete lined artificial canal section	.014

We have assumed that in the winter time at least 7½% of the transmitted water will be required for the proper skimming off of ice, snow and frazil that will

accumulate in the 69,700 feet of water transmission between the intake and the forebay. This 7½% of water should be diverted at the point shown on Drawing No. 3438, marked "Ice Chute," and therefore will not be available for power purposes. We have assumed the efficiency of the turbines to be 91%, and that of the generators 96%, including excitation and transformer losses.

10. The above assumptions for friction losses are not agreed to by your engineers. We are prepared to submit important authorities fully supporting our opinion. We hold strongly to the view that optimism in such a fundamental assumption as friction loss is very dangerous practice especially when so small an expenditure is required to assure safety and where the assumptions of your engineers are unsupported by practical experience. In addition to the foregoing we invite your attention to the fact that this power plant is to depend on an open canal system over 13 miles long for its water supply, and to the fact that such an open canal system will inevitably have its discharging capacity appreciably reduced by debris that will fall into the canal and cannot practicably be removed in spite of any precautions that can be installed. The foregoing plus six curves in the 13-mile stretch of open canal and plus the indeterminate losses that are bound to occur in the 1,600-foot long whirlpool section due to eddies resulting from changing velocities therein, call for the adoption of our recommendations if future heavy losses of power are to be avoided. The foregoing difficulties cannot be corrected for the canal sections after the plant is in operation without shutting down the plant entirely.

11. Resulting Operating Heads.—For reasons set forth in our report of August 7th we have assumed that the elevation of the water at the intake will be 558.00, and at the tail race it will be Elevation 243.00 under present conditions. On the foregoing basis we find the net operating heads to be as follows:

(*a*) For 14,500 c.f.s. used according to present designs..... 292.3 ft.
(Present canal design will carry only 14,500 c.f.s.)

(*b*) For 15,000 c.f.s. used according to recommended changes in present designs ..... 301.04 ft.

(*c*) For 20,000 c.f.s. used according to recommended changes in present designs ..... 299.04 ft.

It should be noted here, however, with the respect to the Elevation 243.00 that the future requirements in Canada for hydro-electric power will undoubtedly require the regulation of the level of Lake Ontario in a manner that will make the tail water elevation after regulation, four feet higher than now obtains, or Elevation 247.00. It should also be noted that at various times in the future, due to ice gorges that will form from time to time in the vicinity of this power house, that the elevation of tail water will be considerably increased for short periods, causing reductions of operating heads and reducing the power output appreciably. To take care of consumers at such times of reduction of head the operating department should be allowed by future treaty arrangements to divert such an excess above the normal diversion as will compensate for the temporary loss of head.

12. Resulting Amounts and Costs Per H.P.—For the above three plans, the results will be as follows:

For 11 (*a*)—

Total H.P.	389,000
Total Cost	$76,636,931.00
Cost per H.P.	$197.00

For 11 (*b*)—
Total H.P. 414,600
Total Cost $73,531,635.00
Cost per H.P. $177.36

For 11 (*c*)—
Total H.P. 549,200
Total Cost $88,930,506.00

A comparison between 11 (*a*) and 11 (*b*) shows the following:

11 (*b*) costs less than 11 (*a*) by..... $3,105,000.00
II ((b) gives 25,600 extra H.P. This extra H.P., according to 11 (*a*) costs $197.00 per H.P., thus producing a value for this extra H.P. of ..... $ 5,043,200.00
Total gain in value by adopting Paragraph 13 .....$8,148,200.00

A comparison between 11 (*a*) and 11 (*c*) shows the following:

Amount of H.P. in 11 (*c*)..... 549,000
Amount of H.P. in 11 (*a*)..... 389.000

Difference ..... 160,000 H.P.
Value of 160.000 H.P @ $197.00 .....$31,520,000.00
Less extra cost of 11 (*c*) over 11 (*a*) $12,293,575.00

Total gain in value by adopting 11 (*c*) $19,226,425.00

NOTE: See Paragraphs 1 and 2 of Appendix A for recommendation re 11 (*c*).

13. ROCK SECTION OF THE CANAL.—As noted in Paragraph 10 we find ourselves unable to agree with your engineers as to the discharging capacity of the entire water transmission system and particularly with reference to the rock section of the canal, 39,000 feet long. With respect to the rock section of the canal, your engineers have furnished us with prints from their Drawing No. 7-3-225-E on which is indicated the slope of the bottom of the rock section of the canal from Station 65.00 to the beginning of the forebay at Station 452.87. This drawing shows that the slope of the bottom of the canal is .0002113. That part of the rock section of the canal where excavation is now completed shows the above slope, and we find that your engineers correctly adopted this slope at the time when the quantity of water to be transmitted was 6,500 cubic feet per second. Since the adoption of 6,500 c.f.s. as the amount of water to be transmitted, your engineers have increased the quantity of water to be transmitted to 15,000 c.f.s. but have not increased the slope of the canal, and as far as we know have not increased any other dimension of the canal that would increase its discharging capacity. In any event the canal as now laid out is not the correct plan for 15,000 c.f.s. The use of the present design for this canal will cause you to lose 25,600 H.P. unless you adopt the following recommendation, to wit:

Increase the slope of the floor of the canal to such an amount as will be determined by the use of .014 as the value of the coefficient "N" in the Kutter formula so that the floor of the canal and the surface of the 15,000 c.f.s. flowing therein are parallel.

This recommendation will call for an extra excavation in the bottom of the canal of 291,300 cubic yards and a small amount of increased lining, at a total cost of $1,315,000.00. If the foregoing advice is followed you will secure an additional 25,600 H.P. at a cost of $51.37 per H.P., an opportunity you cannot

afford to lose. In the above determination it is not necessary to include any additional items, as all other expenditures are already in the estimate.

14. Extra Recommended Facilities.—In Paragraph 12 we show how increased values amounting to $8,148,200.00 can be effected by the use of 15,000 c.f.s., and $19,226,425 by the use of 20,000 c.f.s. Attention should here be directed to the facts that the estimates for the total cost of 11 (*b*) and 11 (*c*) include—

Skimming works in front of forebay, Paragraph 12, Appendix A..$499,350.00
Additional distributing system in forebay, Par. 13, Appendix A..$225,000.00
Extra allowance for power house foundations, Par. 16, Appendix A$250,000.00
Total for extra facilities not credited in Par. 12, and not included in existing design $974,350.00

15. Intake.—Paragraph 6 of Appendix A sets forth a saving of $2,777,453.00 as possible by abandoning your present plan of intake and substituting therefor a fixed masonry boom. The fixed masonry boom arrangement has in addition to its less cost the certainty in advance of its construction that it will be absolutely effective for the work it will be called upon to perform.

No more severe skimming tests at an intake have ever been applied than is found in the successful twelve years' experience at the Toronto Power Company. This plant has not been shut down or lost a kilowatt of energy on account of floating ice or frazil in the entire history of its operation. No other plant at Niagara Falls on either side of the river has to its credit anything approaching a similar record. It is located immediately below the Chippawa intake and in the design of the intake which we have worked out to cost $581,640.00, we have used even more conservative flow ratios than have been successfully used at the Toronto Company.

The success of the recommended intake depends solely upon the fact that the velocity of the water on the outside of the intake will be so largely in excess of the velocity of the water that passes through the submerged openings of the intake to the Welland River as to prevent absolutely any suction through the intake opening. Our intake does away entirely with the expense of the lock in the adopted design. Our intake design has been used for six years with entire success under very severe ice conditions at Keokuk, Iowa.

The plan of intake which your engineers have adopted is, in our judgment, unfortunate, is an experiment based upon theoretical analysis and a small model experiment at Niagara Falls, which in no sense represents working conditions. The gathering dam at the Toronto Power Company shows large volumes of gravel and stone and water-logged debris travel down the bed of the river at all seasons of the year. This material has accumulated in The Toronto Power Company forebay to an extent requiring almost continuous dredging to keep the same out of the screen room. It is a well known fact that in the winter time frazil moving along the bed of all swift rivers picks up considerable quantities of stone and carries it along to some point of lodgment.

The history of the Cedars plant from the beginning of its operation up to October 15th of this year has been one of continuous labor by divers in front of the Cedars screen rack in removing by the use of derricks loading into scale boxes many hundred yards of rock and heavy water-logged debris that of itself will plug shut the intake slots of the entire finger system in your adopted intake design. The adopted design is such as to very effectively reach out and gather into and onto itself all of the materials that will come down the river bed for 600 feet of its width.

On October 15th of this year, we saw scale boxes come out of the water in front of a screen at Cedars where stones varying from one cubic foot to four cubic feet had been dragged to the space immediately in front of these screens. The operators at Cedars informed us that this operation is a continuous performance with them. The river stretch between the Cedars intake to slack water in Lake St. Francis is only about a quarter of the length of the river stretch above your intake to similar slack water in Lake Erie. We are forced to the conclusion because of specific observations, which are in no sense theoretical, that the six intake fingers will fill up and plug up to such an extent as to make their use impracticable.

The assertion of your engineers that if anything of the above sort happens they can produce a sufficient head to correct the difficulty is an impossible conclusion. It is our opinion that after a very few years of operation of your proposed intake design that it will be so plugged up with material that cannot be removed because of the design of the intake fingers, that you will have worse conditions at the Chippawa intake than have ever obtained at the intake of the Canadian Niagara Power Company.

Even if it could be admitted, which it cannot, that the adopted design would work as satisfactorily as the recommended boom design, there would still be no justification for the wasting of $2,777,453.00.

16. Forebay and Ice Chute.—In paragraphs 12 and 13 of Appendix A, we discuss the necessity for skimming works at the head of the forebay at Station 444.00 and certain modifications we believe necessary in the forebay basin if continuous operation of the plant is to be reasonably expected.

When the plant is completed and in operation as now designed, the velocity of the water in the rock section of the canal will vary from 13 feet per second maximum, down to less than two feet per second on Sundays. These velocity conditions during the low temperatures of winter will cause large volumes of thin ice to form on the 13-mile surface of the water transmission system. The changes of velocity will also cause a very considerable amount of frazil to form, and the frazil, ice and snow that will accumulate over this 13-mile open canal system will produce an amount of ice debris that will have to be skimmed away from the forebay, failing in which the forebay itself will fill up and shut off the entire flow from the turbines.

The foregoing assertions are not made in a spirit of alarm, but are based upon practical knowledge of what will happen at this plant. In order to take care of such an inevitable situation, we have recommended the ice chute and also have recommended that the forebay itself be provided with a distributing device that will keep the floating ice and frazil that is not taken out by the ice chute, well distributed over the entire width of the forebay at the screens to the forebay ice chutes, thus preventing what would otherwise result in a massing of the debris at the center of the screen house with results that must be avoided. We therefore beg to reaffirm all of the recommendations with respect to the above two topics.

17. Screen House and Penstocks.—In paragraphs 14 and 15, Appendix A, we have made reference to some changes in design that we would recommend in the general report in existing designs for the screen house and penstocks. Owing to the delays which have ensued in the preparation of this final report, over which we have had no control, and owing to your desire for an immediate presentation of this final report, we will omit any further discussion of either subject.

18. Labor.—In paragraph 22 of Appendix A, we refer to some special recommendations with reference to the handling of labor that are to be submitted in the general report.

With respect to the foregoing our observation of the labor performance on this entire job has convinced us that broadly speaking, this labor has been very inefficient. This inefficiency in our judgment has not been due to any lack of zeal or intelligence on the part of those immediately responsible for the handling of the labor, and we believe that the Construction Superintendent, Mr. George Angell, has achieved the best results that could possibly have been obtained as far as labor is concerned under the very trying conditions through which Mr. Angell and his subordinates have passed.

All over the world it has always been observed that labor working for any government is always abnormally inefficient. The degree in which such labor fails to perform a reasonable day's work varies. The outstanding, universal explanation of this difficulty of labor is found in the fact that a rich government is paying for their time.

We believe that a very considerable reduction in the cost of the work still to be performed and in the time in which it can be performed can be effected by introducing a practical bonus system on the entire job. This bonus system would provide that all of the labor excepting division superintendents would be put on a wage at least ten per cent below what is now current and that such a wage would be called a base wage. In addition to the base wage, the labor should be paid monthly a bonus based upon the relationship between the cost of the work as they performed it and the estimated cost of the Construction Department, the savings to be divided on a fifty-fifty basis. Such an arrangement if honestly administered by the Construction Department, and if arranged so that the labor itself could have three or four representatives to check up the working of the bonus system, would place the entire organization on a semi-profit sharing basis that would give a stimulus to the undertaking not otherwise obtainable. We see no reason why honest profit-sharing cannot be introduced on work where such large quantities exist with respect to so few different kinds of labor.

19. Quantities and Unit Costs.—All quantities referred to in this estimate have been checked by our own instrumental surveys with sufficient accuracy to overtake all errors above 5%. We have checked the accounting departments in Toronto and Niagara sufficiently to warrant our use of the figures quoted. Unit costs used are based upon past performance of the Construction organization and upon cost conditions and construction plans in commission September 1, 1920. If labor and material costs after September 1, 1920 recede then our estimates of costs herein will recede by the same percentage and *vice versa*.

20. Drawing No. 3439. Reference is made to Drawing No. 3439 on which is indicated a set of profiles taken along the center line of the water transmission from the Welland River to the Niagara River. The profile is self-explanatory.

On this same sheet we show two charts, one with reference to the earth excavation and the other with respect to the rock excavation.

It will be observed on the earth excavation chart that on May 1, 1920, 54% of the necessary earth excavation was yet to be done and 46% had been completed. The relative location and the proportions obtaining at the various stations are shown on the chart. On May 1, 1920, 79% of the rock was yet to be excavated, and 21% was completed.

The uncompleted excavations, both of rock and earth, are more difficult of performance than the percentages that have been completed because of excess of moisture that will be formed in the uncompleted work.

21. Drawing No. 3440.—Drawing No. 3440 is a chart showing the comparative costs for the ultimate installations for the three cases specified, and the remarks made with respect to Drawing No. 3441 will apply to this drawing.

22. Drawing No. 3441.—On Drawing No. 3441 we have shown graphically and analytically the various elements of costs that make up the totals that are referred to in detail in Appendix A. It has occurred to us that an analysis of this kind would have given an added opportunity for comprehending the magnitude of the elements in this project.

We desire at this time to mention particularly the item of interest charges. The interest charges have been compounded semi-annually at 6½%, and in computing the total interest charges for the different cases, we have assumed that when five units are completed and in operation, the selling price for the current from these five units will be sufficient to carry all interest charges for the entire plant up to that date, and that the interest charges for additions to the plant, until the complete installations are ready for operation, will be installed in units not calling for over one year of interest during their construction period.

It is proper for us to set forth the above method of arriving at this complex question in order to have a basis for your consideration. If the amount at which the current from the first five units is charged is too low a price to carry all of the previous interest charges, then the estimates which we have submitted for the total cost and the horsepower costs will be too low by the amount of such deficiency.

23. Time of Completion.—There has been a wide difference of opinion as between your engineers and ours regarding the time this plant will be completed, ready for operation. We have based all of our estimates on our belief that five units will not be completed ready for commercial operation before January 1, 1923. We agree that by good luck it may be possible to start operation with two units three months earlier than January 1, 1923. It is quite feasible to start the plant before all of the work in the Welland River section is completed, but the Welland River section is not the controlling factor in this time study.

There are two controlling factors in the time study and they are, first, the time in which the rock canal can be completed, and second, the time when the power house and its contents can be completed sufficiently to admit of commercial use. Much has been said on this subject of the time of completion. We have therefore given the uncompleted work to be done several check studies with the result in each case that we are unable to modify or change the views above expressed.

24. Whirlpool Section.—In Paragraph 11, Appendix A, we speak of the whirlpool section. We desire to add to paragraph 11 as follows:

The whirlpool section is incapable of any engineering or mathematical analysis. The efficiency of the designs for this section will have to be determined by practical judgment. We are very certain that the slope 1½ : 1 as now adopted is too steep, and when this section is filled with water, the supporting loose rock will not stand a slope of 1½ : 1 and will slide into a flatter angle of repose, probably 2 : 1 or at least 1¾ : 1. It would therefore seem unwise to spend the large sum of money required for concrete facing for the whirlpool section until the

supporting rock had been tested as to the angle of repose when immersed. Several checks of the angle of repose for immersed rock were made of the same class of rock you will use in this whirlpool section, and these checks confirm the recommendations here made.

We have, therefore, recommended that at the two ends of the whirlpool section (about sixteen hundred feet apart between Stations 330.00 and 350.00) to be blocked off by the construction of temporary dams built to such heights as will permit of filling this section to a test elevation of 570, and we believe that this Elevation 570 should be maintained for a period of eight months. The application of such a test will go far to settle the sufficiency of the artificial fill that has been made for the support of the canal at this place, and at the same time will allow the loose rock slope walls to adjust themselves to their natural immersed slope. If this test is not adopted, you will find that the concrete facings will be disrupted by slides when the canal is first filled, requiring that the canal system be unwatered for their repair.

25. Plant Testing and Future Power Growth in Canada.—The efficiency and capacity of any hydro-electric plant can be determined only when minimum conditions of water supply and head are encountered. Where an investment of over $75,000,000.00 is contemplated the future should be rationally estimated in order to make certain that the investment will now fit into what is really in the best interest of Canada in the future. This we have attempted to do in the recommendations herein. Power consumers in Canada and the United States have already over-suffered from failure to look into the future and from ill-considered installations at Niagara and on the St. Lawrence River. The Hydro-Electric Commission plans at Chippawa should be in full harmony with future power needs in Ontario, and the intake levels and plans correspondingly adjusted. The amounts of power we have specified are those amounts which will be deliverable when further Niagara River power diversions reduce the intake level to 558. Plant tests from three or five units will have practically no value in indicating what the actual, practical future total capacity of the plant will be.

26. 20,000 C. F. S. Diversion.—We are firmly of the opinion that the best interests of Ontario for all future time require that the Chippawa plant be now enlarged to 20,000 c.f.s. capacity, and that all recommendations herein related to the use of 20,000 c.f.s. should be adopted immediately.

27. Conclusion.—In conclusion, when we undertook this work the first of May, we instructed Mr. D. P. Cooper, and through him all of our engineers who were placed on this problem, to the effect that in every reasonable way we were to seek conclusions that would agree with your engineering and construction departments. The spirit in which the work was undertaken was and is now a desire to approve. The engineering profession for many years in America and in Canada, and in other parts of the world has been justly accused of an all prevalent tendency to criticise and an unwillingness to see good in the work of others. Some observers go so far as to say that the above difficulties should not be applied to engineers alone, but should be applied to all classes of people.

That we have been forced to differ with your engineers in important particulars is a matter of very deep regret with us all. We have not called your attention to several other criticisms that we could also enumerate for the reason we believe no practical good would result to you in our following such a course further.

All of the differences we have herein discussed, however, have been taken up in detail with your engineers without agreement with them, and we have therefore only one recourse and that is to file with you the foregoing.

Yours very truly,

(Signed) HUGH L. COOPER & CO.

[Copy]

APPENDIX "A"

REPORT

ON

CHIPPAWA HYDRO-ELECTRIC PROJECT

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

LETTER OF TRANSMITTAL

to

SIR ADAM BECK

Chairman

HUGH L. COOPER & CO.

Consulting Engineers

101 Park Avenue

New York City

August 7, 1920

[Copy]

New York, N.Y.,
August 7, 1920.

Sir Adam Beck, Chairman,

Hydro-Electric Power Commission of Ontario,

Toronto, Ontario, Canada.

Sir:

On April 22, 1920, your Commission gave us instructions calling for a general report from us on your Chippawa Hydro-Electric Power Project. Verbal instructions from you have emphasized the desire of the Commission that our examinations should be thorough and comprehensive, and thus enable us to submit findings of a definite character. Our work since May 5th, 1920, has been continuous with as many engineers and accountants as we believed necessary for the faithful discharge of the duty you have imposed.

We find the general plan of an open canal system as located on the plans submitted to us by your engineers, to be the best that could have been adopted when the history of your project is fully understood. The project as a whole is the most ambitious hydro-electric undertaking yet devised by engineers on this continent or elsewhere.

We believe the expenditures which you will be required to make on this project will be justified by the beneficial results which will accrue to the industrial life of the Province of Ontario.

The report of our findings and recommendations will consist of the following digest and summary, and a complete supplementary report, which will follow later, giving details of all our investigations and reasons for our recommendations.

1. This Project as originally planned called for the use of 6,500 c.f.s. and was later increased to 15,000 c.f.s. We are of the opinion that this quantity of water should be increased to 20,000 c.f.s. Owing to the type of water transmission adopted by your engineers, this increase in the use of water is possible without any appreciable loss of money for work thus far completed.

2. The question of the availability of 20,000 c.f.s. is of first importance. The United States Government engineers are about to recommend to the American Federal Congress that 80,000 c.f.s. be diverted from the Niagara River for power purposes: 40,000 c.f.s by Canada, and 40,000 c.f.s. by the United States.

The inefficient use of water at Niagara Falls has become a serious problem. The American Government is requiring the abandonment of one inefficient plant on the American side. The Commission may ultimately decide that the best interest of the public will be served by an arrangement with the Canadian Niagara Power Company for the use by the Chippawa plant of the 8,225 c.f.s. which are now being inefficiently used by the Canadian Niagara Power Company.

The unused quantity of water under the present Treaty allotments amounts to 6,610 c.f.s. The balance needed to complete the recommended 20,000 c.f.s., namely 1,165 c.f.s. could be taken from the Ontario Power Company.

3. The normal elevation of the water surface at the point of diversion from the Niagara River, as adopted by your engineers is 560.50.

Owing to the imminence of considerable increased diversion from the Niagara River for power purposes above those now permissible, we are of the opinion that the elevation of the water surface at the point of diversion should be taken as El. 558.00. We find that with 15,000 c.f.s. in commission with normal tail water, the minimum operating head will be 292 feet, and with 20,000 c.f.s., this head will be 299 feet.

4. The term "horsepower" as used in this report, will mean an electrical horsepower delivered to the step up transformers in the generator station.

In estimating the quantity of horsepower that will be produced by different plans discussed, we have used the following coefficients:

Kutter's formula has been used for all water transmission determinations where 0.04 has been applied for canal sections in earth, and .04 for concrete-lined canal sections. We have made a total deduction of 7½% of the quantity of water entering the intake, to be used for flushing purposes during the winter season, and to compensate for probable wind losses. The general report will contain our reasons for the use of the foregoing coefficients.

5. We recommend certain changes in your present adopted plans, as follows:

6. Intake.—We believe the design of intake adopted by your engineers should be abandoned, and a fixed masonry boom substituted therefor. We find the plan adopted by your engineers will cost $3,359,093.80. The cost of the substitute fixed boom protection will be $581,640.00.

We are certain the intake proposed by your engineers would be a disappointment if built, for reasons which will appear in our general report. The saving resulting from this recommendation amounts to $2,777,453.80. The fixed boom arrangement proposed follows successful engineering precedents at the Toronto Power Company plant, and at Keokuk, Iowa, and other plants designed by us.

7. Welland River Section.—We recommend that all of the Welland River Section, except that part near Station 244-00, be excavated with slopes 1 : 2, and the excavation be accomplished by the use of a suction dredge instead of the dipper dredge and cableway now being used.

8. Canal Section.—We recommend that the canal section between Stations 0-00 and 45-00 be excavated to slopes 1 : 2 by use of the suction dredge method. If recommendations in paragraphs 7 and 8 are adopted, we estimate the following savings will be effected:

9. Suction Dredge Savings.—On the Welland River Section $635,000.00 for 15,000 c.f.s., and $1,051,000.00 if 20,000 c.f.s. are used.

For the canal section, the saving will be $1,108,000.00 for 15,000 c.f.s. and $1,560,000.00 for 20,000 c.f.s.

Our investigations show that the material referred to in paragraph 9 can be taken out by a suction dredge in 75% of the time required by the methods now planned. In addition to the foregoing, the use of the suction dredge will release a considerable amount of your present equipment, thus further guaranteeing a sufficient amount of apparatus for the balance of your excavations.

The total saving due to the use of the suction dredge method will be $1,743,000.00 if 15,000 c.f.s. are developed, and $2,611,000.00 if 20,000 c.f.s are developed.

10. Bridges.—We are of the opinion that material savings in the cost of uncompleted bridges can be made, but as this phase of the problem calls for

considerable time for precise recommendations, no attempt at specific advice on this subject will be made here.

11. Whirlpool Section.—In the whirlpool section we find your engineers have used the best care possible for this difficult portion of the work, but in view of the unusual conditions that exist in this section, we recommend that a test be made of the stability of the whirlpool section by filling it with water before any concrete lining is placed on the slopes.

12. Skimming Works.—We recommend that near Station 444-0 there be constructed a complete skimming works for the effective removal of floating frazil and snow accumulating between the intake and this station. The cost of this necessary facility we estimate to be $499,350.00.

13. Forebay.—We believe the forebay as now designed for either 15,000 or 20,000 c.f.s requires modifications if satisfactory operating conditions are to be secured.

We recommend the construction and the experimental use of a concrete or wooden model to scale 1 : 20, of the forebay, and a study of the flow data thus produced. This data will prove the necessity for changes in the forebay design, and be a safe guide for the adoption of the most economical plans for this need.

In our estimate we have allowed $225,000.00 for this test, and for the resulting necessary alterations in the design of the forebay.

14. Screen House.—The general designs of screen house and penstock intakes are satisfactory. We will, however, recommend changes in the detail of the design in our general report.

15. Penstocks.—The general design of the penstocks is satisfactory. The question of expansion joints and other details will be referred to in the general report.

16. Power House Foundations.—During the period of our investigations we caused fifteen holes to be bored on the power house site. These disclosed the location and character of the rock which will serve as foundation for the power house. The foundation rock available is a red shale of acceptable quality for bearing purposes. These foundations, however, will be exposed to additional indeterminate and excessive lateral pressures from ice jams that occur in the river at and near the power house site.

We recommend that further borings be made in the river adjacent to the power house site, for the purpose of conclusively ascertaining the extent of the rock slopes. If further explorations show that the present power house location is in any danger from overhanging or insufficient slopes, the present location should be moved back from the river to such a position as good judgment dictates.

We have included in our estimate, $250,000.00 to cover the contingency of a possible change from the present location.

17. Turbines.—The hydraulic machinery under contract with Wm. Cramp & Sons is approved. Your contract requirements with the Wellman-Seaver-Morgan Company, while satisfactory as far as the guarantees are concerned, require special care with respect to a most thorough inspection of all of the work called for by this contract.

18. Valves.—The contract for the Johnson valves is in the main satisfactory, but special care should be devoted to inspection of details of design and shop work.

19. Electrical Apparatus.—The design of the electrical apparatus has not been studied. The statements of your engineers, with respect to the same, have been accepted as satisfactory.

20. Power House Substructure and Superstructure.—The general design of the power house indicates a stable structure, but no examination of the details has been possible for want of time. It seems to us that considerable savings can be effected by a re-design of the power house substructure.

No design of the superstructure has been submitted, but we have estimated that a satisfactory design of superstructure can be provided at a cost not exceeding 40 cents per cubic foot, excluding cranes.

21. Organization.—We are of the opinion that all the engineering and business management connected with the design and construction of this plant with complete authority over every detail therein, should be located at Niagara Falls, Ontario, on the works.

We believe that the accounting system as now installed, is too intricate, and that it should be greatly simplified and thus made to be of the maximum assistance to the Construction Department. We recommend that all accounts be audited by independent, certified public accountants every three months during the construction period. Our estimates of cost have necessarily been based, as far as tools and equipment are concerned, on figures supplied by your Accounting Department.

We recommend that a complete inventory be made at once of all tools machinery and materials that have been bought for this work, and that this inventory be checked every ninety days, in the future, for the guidance of the Engineering and Accounting Department.

We recommend that your Engineering and Construction Departments immediately prepare a work time schedule, setting forth specifically the monthly expected construction progress that is required for the final promised completion ready for commercial operation date.

Upon the adoption of such a schedule, the same should be filed with the Commission, and the Construction Department should thereafter make a monthly report to the Commission setting forth clearly the relationship between actual achievement and the submitted scheduled forecast, for, in no other way can the Construction Management be held accountable.

We recommend that the Construction Department organize, maintain and test at least every ten days an adequate system of fire protection wherever fire could interfere with construction progress, and that special vigilance be displayed in and about rock crushing and concrete mixing plants.

22. Labor.—Special recommendations with reference to the handling of labor will be submitted in the general report.

23. Cost.—The following paragraphs contain the discussion of the final costs and dates of completion for commercial operation, and the details for each case will be set forth in the final report.

Our examination of the records indicates a total expenditure of $19,936,370.86 up to May 1st, 1920, to which should be added $504,000.00 accrued interest from October 31st, 1919 to May 1st, 1920, making a total cost of the work to May 1st, 1920, of $20,440,000.00.

Case I.—If the work is completed according to your present plans using 15,000 c.f.s., we estimate the cost will be as follows:

(A) Amount of H.P.	258,000
Number of Units	5

	Total Cost	$66,423,418 00
	Cost per H.P.	$ 257 45
	Time of Completion	January 1, 1923
(B)	Amount of H.P.	389,000
	Number of Units	9
	Total Cost	$76,636,931 00
	Cost per H.P.	$ 197 00

Case II.—If 15,000 c.f.s. are used, and the recommendations in paragraphs 6 to 23 inclusive are adopted, we estimate the cost will be as follows:

(A)	Amount of H.P.	258,000
	Number of Units	5
	Total Cost	$60,862,892 00
	Cost per H.P.	$ 235 90
	Time of Completion	January 1, 1923
(B)	Amount of H.P.	389,000
	Number of Units	9
	Total Cost	$72,216,635 00
	Cost per H.P.	$ 185 65

24. Available Water.—We are not advised as to how the Commission will procure the above 15,000 c.f.s., and the above costs per horsepower assume that the necessary 15,000 c.f.s. are obtained without expense.

We have suggested in paragraph 2, the acquisition of the Canadian Niagara Power Company by the Commission. Should this be accomplished, the necessary 15,000 c.f.s. would be available.

The arrangement we have in mind would provide for the furnishing to the Canadian Niagara Power Company of the amount of dependable power they now receive from the use of this 8,225 c.f.s., less an amount of power that equals the existing costs of operation and shutdowns due to ice.

The Canadian Niagara Power Company plant was unfortunately designed in the beginning, as was generally believed at the time the plan was adopted, and as has been continuously proven throughout its operating existence to date, and this fact should be taken actively into consideration when the amount of positive dependable power the Canadian Niagara Power Company would receive is being determined. Each winter season of its operation it has suffered marked interruption from ice trouble, and recently these interruptions have been as high as 40% of the total capacity.

If the foregoing arrangement is effected, the units in the Canadian Niagara Power Company plant thus made idle could be kept in reserve for future emergency use.

If the additional 8,225 c.f.s. are obtained as recommended above, and the compensation therefor is effected as suggested, then the amount of power mentioned in Cases I and II should be reduced by 80,000 H.P., thus producing costs per H.P. as follows:

Case I.—
For 9 Units ..... $248 00 per H.P.

Case II.—
For 9 Units ..... $233 71 per H.P.

25. Case III.—If 20,000 c.f.s. are used and the recommendations mentioned in paragraphs 6 to 23 inclusive, are adopted, we estimate the cost to be as follows:

(A)	Amount of H.P.	311,000
	Number of Units	6
	Total Cost	$71,988,626 00
	Cost per H.P.	$ 231 47
	Time of Completion	January 1st, 1923
(B)	Amount of H.P.	549,000
	Number of Units	12
	Total Cost	$88,930,506 00
	Cost per H.P.	$ 162 00

If 20,000 c.f.s. are obtained in the manner recommended in paragraph 2, and the power compensated for as suggested in paragraph 24, then the total available power in Case III, (B) will be reduced by that amount, or as follows:

(B) 549,000 H.P. minus 80,000 H.P. equals 469,000 H.P. Therefore, the unit cost becomes:

(B) 469,000 H.P. @ $189.61 per H.P.

26. The foregoing figures show by way of justification of enlargement of the plant to 20,000 c.f.s. that you will secure 469,000 H.P. at a cost of $58.39 per H.P. less than by using 15,000 c.f.s. It will be observed that this great saving is accomplished by a full compensation to existing interests at Niagara Falls, and at the same time there is yielded for the benefit of the Ontario consumers their much needed power supply at a cost not to exceed 30% of the cost by steam, even if steam were available.

27. In conclusion we wish to extend to your entire organization our appreciation of the aid they have given us in the work preceding this report. Investigations and reports of this character are always an annoyance to any organization. Mr. Acres and all his men have provided for our needs in a spirit of co-operation that was as unusual as it was welcome.

Yours very truly,

REPORT

ON

CHIPPAWA HYDRO-ELECTRIC PROJECT

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

COST ESTIMATES

HUGH L. COOPER & Co.
Consulting Engineers
101 Park Avenue
New York City

August 7, 1920

EXPLANATION

This report covers six different cost estimates, each of which is to be indentified by its special serial number.

CASE I. Estimate of cost of Project as designed by the Hydro-Electric Power Commission Engineers wherein Hugh L. Cooper & Company's quantities and unit prices have been applied.
Quantity of water, 15,000 c.f.s.

CASE II. Estimate of cost of Project wherein Hugh L. Cooper & Company have introduced modifications in design, and applied their quantities and unit prices.
Quantity of water, 15,000 c.f.s.

CASE III. Same as Case II using 20,000 c.f.s.

The letter "C" indicates the cost to complete to January 1, 1923. This date applies to 5 and 6 units only.

The numbers 5, 6, 9 and 12 indicate the number of units.

CONTINGENCIES

Contingencies in this estimate are treated as follows:

Ten per cent. is added to the neat-line excavation quantities in earth for overcut.

Seven and one-half per cent. is added to all other quantities to provide for changes in design and contingencies.

The unit price applied to steel in the penstocks is $225.00 per ton. The tonnage includes an excess of 10 per cent. for the first 100 feet in elevation drop beginning at the forebay and 15 per cent. allowance for the remainder. These percentages are exclusive of the seven and one-half per cent. mentioned above.

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate 1-C-5

(A) INTAKE

COFFERDAM					
Steel Sheet Piling	2,902½	tons	@	$125.00	$ 362,812 50
Fill	188,125	c. y.	@	1.20	225,750 00
Pumping					50,000 00
EXCAVATION					
Earth Excavation	380,550	c. y.	@	.65	247,357 50
Rock Excavation	21,500	c. y.	@	3.50	75,250 00
MASONRY					
Concrete, plain	50,525	c. y.	@	15.00	757,875.00
Concrete, reinforced	34,400	c. y.	@	40.00	1,376,000.00
STRUCTURAL STEEL					
Gate Beams	223,063	lbs.	@	.10	22,306.30
MISCELLANEOUS					
C. I Spacers	118,250	lbs.	@	.15	17,737.50
Gantry Crane					15,000.00
Two Lock Gates and Oper. Mach.					100,000.00
Fill, Earth	169,850	c. y.	@	.60	101,910.00
Rip, Rap	7,095	c. y.	@	1.00	7,095.00
Total					$3,359,093.80

(B) WELLAND RIVER

Earth Excavation	2,541,073	c. y. @	$ .70		$1,778,751 10
Rip Rap	26,875	c. y. @	1.00		26,875.00
Concrete	1,613	c. y. @	16.00		25,808.00
Total					$1,831,434 10

(C) POWER CANAL

CANAL EARTH SECTION					
Earth Excavation	2,441,201	c. y. @	$ 1.10		$2,685,321 00
Rock Excavation	77,726	c. y. @	3.50		272,041 00
Rock Lining	465,690	c. y. @	.15		69,853.50
Concrete	29,563	c. y. @	14.00		413,882.00
Total					$3,441,097.60
CONTROL WORKS					
Rock Excavation	430	c. y. @	5.50		2,365 00
Concrete, reinforced	1,828	c. y. @	40.00		73,120.00
Gate with Rollers, Steel	240,800	lbs. @	.10		24,080.00
Gate Operating Machinery	107,500	lbs. @	.40		43,000,00
Bridge over Canal					25,000.00
Total					167,565.00
CANAL ROCK SECTION					
Earth Excavation	3,011,036	c. y. @	1.10		3,312,139.60
Rock Excavation	2,939,365	c. y. @	3.50		10,287,777 50
Rock Fill	1,149,498	c. y. @	.15		172,424.70
Concrete in Walls	50,525	c. y. @	14.00		707,350.00
Concrete in Lining	285,090	c. y. @	14.00		3,991,260.00
Concrete in Whirlpool	49,772	c. y. @	14.00		696,808 00
Anchor Rods, Steel	681,550	lbs. @	.20		136,310.00
Total					19,304,069.80
Canal Earth Section					3,441,097.60
Control Works					167,565.00
Canal Rock Section					19,304,069.80
Total Canal					$22,912,732.40

(D) FOREBAY

Earth Excavation					Completed
Rock Excavation					Completed
Concrete Lining	23,220	c. y. @	14.00		325,080.00
Concrete Walls	3,978	c. y. @	14.00		55,692.00
Anchor Rods, Steel	23,650	lbs. @	.20		4,730.00
Total					$385,502.00

(E) SCREEN HOUSE

SUBSTRUCTURE					
Earth Excavation					Completed
Rock Excavation					Completed
Concrete, reinforced	26,810	c. y. @	$ 40.00		$1,072,400.00
Structural Steel in Racks	323,575	lbs. @	.075		24,268.13
Structural Steel in Gates	1,088,233	lbs. @	.075		81,617.48
Structural Steel in Checks	437,525	lbs. @	.10		43,752.50
Ice Chute Gate and Rig					25,000.00
Rock Fill	5,483	c. y. @	1.50		8,224.50
Earth Fill	5,052	c. y. @	3.00		15,156.00
Superstructure					237,405.00
Miscellaneous					75,000.00
Total					$1,582,823 61

(F) PENSTOCKS

Tunnel Rock Excavation	6,450	c. y. @	$ 10.00		$ 64,500.00
Open Cut Rock Excavation	25,263	c. y. @	3.50		88,420 50
Concrete, plain	15,588	c. y. @	16.00		249,408.00
Concrete, reinforced	2,795	c. y. @	40.00		111,800.00

Structural Steel	5,535,712	lbs. @	0.1125	622,767.60
Rip Rap, Wall	12,363	c. y. @	3.00	37,089 00
Total				$1,173,985.10

(G) POWER HOUSE

COFFERDAM				
Concrete, plain	4,085	c. y. @	$ 15.00	$ 61,275.00
Pumping				15,000.00
Removal Charges				45,956.00
SUBSTRUCTURE				
Rock Excavation	298,689	c. y. @	3.50	1,045,411.50
Concrete, reinforced	59,125	c. y. @	32.00	1,892,000.00
Tail Race Excavation	13,975	c. y. @	5.50	76,862 50
Superstructure				1,579,500.00
Miscellaneous				200,000.00
Emergency Fund				200,000.00
Total				$5,116,005.00

(H) HYDRAULIC EQUIPMENT

COMPLETE F.O.B.				
Queenston				$1,829,840 94
Storage, Transportation, Erection	3,000	tons @	$ 60.00	180,000.00
Total				$2,009,840,94

(I) ELECTRICAL EQUIPMENT

Complete in Place $4,752,160.00

(J) RIGHT OF WAY

Acquired.

(K) BRIDGES

$1.534,023.82

SUMMARY

(A) INTAKE	$ 3,359,093.80
(B) WELLAND RIVER	1,831,434.10
(C) POWER CANAL	22,912,732.40
(D) FOREBAY	385,502.00
(E) SCREEN HOUSE	1,582,823.61
(F) PENSTOCKS	1,173,985.10
(G) POWER HOUSE	5,116,005.00
(H) HYDRAULIC EQUIPMENT	2,009,840.94
(I) ELECTRICAL EQUIPMENT	4,752,160.00
(J) RIGHT OF WAY	Completed
(K) BRIDGES	1,534,023 82
Total	$44,657,600.77
ENGINEERING ASD OVERHEAD 8 per cent.	3,572,608 06
Total	$ 48,230,208.83
INTEREST CHARGES	
Interest at 6½% per annum, compounded semi-annually	4,193,209.55
Total	$52,423,418.38
TOTAL DISBURSEMENTS	
To May 1st, 1920, plus interest compounded annually to January 1st, 1923	$14,000,000.00
GRAND TOTAL	$66,423,418 38

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate 1-C-9

(A) INTAKE

COFFERDAM					
Steel Sheet Piling	2,902½	tons	@	$125.00	$ 362,812.50
Fill	188,125	c. y.	@	1.20	225,750.00
Pumping					50,000 00
EXCAVATION					
Earth Excavation	380,550	c. y.	@	.65	247,357 50
Rock Excavation	21,550	c. y.	@	3.50	75,250 00
MASONRY					
Concrete, plain	50,525	c. y.	@	15.00	757,875 00
Concrete, reinforced	34,400	c. y.	@	40.00	1,376,000 00
STRUCTURAL STEEL					
Gate Beams	223,063	lbs.	@	.10	22,306 30
MISCELLANEOUS					
C.I. Spacers	118,250	lbs.	@	.15	17,737 50
Gantry Crane					15,000 00
2 Lock Gates and Oper. Machine					100,000 00
Fill, Earth	169,850	c. y.	@ $	.60	101,910 00
Rip Rap	7,095	c. y.	@	1.00	7,095 00
Total					$3,359,093 80

(B) WELLAND RIVER

Earth Excavation	2,541,073	c. y.	@ $	.70	$ 1,778,751 10
Rip Rap	26,875	c. y.	@	1.00	26,875 00
Concrete	1,613	c. y.	@	16.00	25,808 00
Total					$ 1,831,434 10

(C) POWER CANAL

CANAL EARTH SECTION					
Earth Excavation	2,441,201	c. y.	@ $	1.10	$ 2,685,321 10
Rock Excavation	77,726	c. y.	@	3.50	272,041 00
Rock Lining	465,690	c. y.	@	.15	69,853 50
Concrete Walls	29,563	c. y.	@	14.00	413,882 00
Total					$ 3,441,097 60
CONTROL WORKS					
Rock Excavation	430	c. y.	@	5.50	2,365 00
Concrete, reinforced	1,828	c. y.	@	40.00	73,120 00
Gate with Rollers, Steel	240,800	lbs.	@	.10	24,080 00
Gate Operation Machinery	107,500	lbs.	@	.40	43,000 00
Bridge over Canal					25,000 00
Total					$ 167,565 00
CANAL ROCK SECTION					
Earth Excavation	3,011,036	c. y.	@	1.10	3,312,139 60
Rock Excavation	2,939,365	c. y.	@	3.50	10,287,777 50
Rock Fill	1,149,498	c. y.	@	.15	172,424 70
Concrete in Walls	50,525	c. y.	@	14.00	707,350 00
Concrete in Lining	285,090	c. y.	@	14.00	3,991,260 00
Concrete in Whirlpool	49,772	c. y.	@	14.00	696,080 00
Anchor rods, steel	681,550	lbs.	@	.20	136,310 00
Total					$ 19,304,069 80
Canal Earth Section					3,441,097 60
Control Works					167,565 00
Canal Rock Section					19,304,069 80
Total Canal					$ 22,912,732 40

(D) FOREBAY

Earth Excavation	Completed				
Rock Excavation	Completed				
Concrete Lining	23,220	c. y.	@ $	14.00	$ 325,080 00
Concrete Walls	3,978	c. y.	@	14.00	55,692 00
Anchor Rods, Steel	23,650	lbs.	@	.20	4,730 00
Total					$ 385,502 00

(E) SCREEN HOUSE

SUBSTRUCTURE					
Earth Excavation	Completed				
Rock Excavation	Completed				
Concrete, reinforced	26,810	c. y.	@ $	40.00	$ 1,072,400 00
Structural Steel in Racks	323,575	lbs.	@	.075	24,268 13
Structural Steel in Gates	1,088,233	lbs.	@	.075	81,617 48
Structural Steel in Checks	437,525	lbs.	@	.10	43,752 50
Ice Chute and Rig					25,000 00
Rock Fill	5,483	c. y.	@	1.50	8,224 50
Earth Fill	5,052	c. y.	@	3.00	15,156 00
Superstructure					406,980 00
Miscellaneous					100,000 00
Total					$ 1,777,398 61

(F) PENSTOCKS

Tunnel Rock Excavation	11,126	c. y.	@ $	10.00	$ 111,260 00
Open Cut Rock Excavation	35,475	c. y.	@	3.50	124,162 50
Concrete, plain	26,875	c. y.	@	16.00	430,000 00
Concrete, reinforced	2,795	c. y.	@	40.00	111,800 00
Structural Steel	9,226,187	lbs.	@	0.1125	1,037,946 04
Rip Rap Wall	19,135	c. y.	@	3.00	57,405 00
Total					$ 1,872,573 54

(G) POWER HOUSE

COFFERDAM					
Concrete, plain	6,880	c. y.	@ $	15.00	$ 103,200 00
Pumping					25,000 00
Removal Charges					77,400 00
SUBSTRUCTURE					
Rock Excavation	375,014	c. y.	@	3.50	1,312,549 00
Concrete, reinforced	99,975	c. y.	@	32.00	3,199,200 00
Tail Race Excavation	23,650	c. y.	@	5.50	130,075 00
Superstructure					2,673,000 00
Miscellaneous					250,000 00
Emergency Fund					250,000 00
Total					$ 8,020,424 00

(H) HYDRAULIC EQUIPMENT

Complete, F.O.B. Queenston					$ 3,233,000 94
Storage, Transportation, Erection..	5,400	tons	@ $	60.00	324,000 00
Total					$ 3,557,000 94

(I) ELECTRICAL EQUIPMENT

Complete in Place ..... $ 8,417,360 00

(J) RIGHT OF WAY

Acquired

(K) BRIDGES

$ 1,534,023 82

SUMMARY

(A)	INTAKE	$ 3,359,093 80
(B)	WELLAND RIVER	1,831,434 10
(C)	POWER CANAL	22,912,732 40
(D)	FOREBAY	385,502 00
(E)	SCREEN HOUSE	1,777,398 61
(F)	PENSTOCKS	1,872,573 54
(G)	POWER HOUSE	8,020,424 60

(H) HYDRAULIC EQUIPMENT	3,557,000 94
(I) ELECTRICAL EQUIPMENT	8,417,360 00
(J) RIGHT OF WAY	Completed
(K) BRIDGES	1,534,023 82
Total	$ 53,667,543 21
ENGINEERING AND OVERHEAD 8%	4,293,403 45
Total	$ 57,960,946 66
INTEREST CHARGES	
Interest at 6½% per annum compounded semi-annually	4,675,984 34
Total	$ 62,636,931 00
TOTAL DISBURSEMENTS	
To May 1st, 1920, plus interest compounded annually to January 1st, 1923	14,000,000 00
GRAND TOTAL	$76,636,931 00

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate II-C-5

(A) INTAKE

EXCAVATION						
Earth for Piers	18,275	c. y.	@ $	.65	$	11,878 75
Dredging	80,625	c. y.	@	.45		36,281 25
PIERS						
First Cost of Caissons						40,000 00
Installation of Caissons	each			$3,000.00		111,000 00
Concrete, plain	7,955	c. y.	@	15.00		119,325 00
Grillage	215	M FBM		120.00		25,800 00
BOOMS						
Concrete, reinforced	5,237	c. y.	@	40.00		209,480 00
PONTOONS						
Structural Steel	268,750	lbs.	@	.10		26,875 00
Painting						1,000 00
Total					$	581,640 00

(B) WELLAND RIVER

Earth Excavation	1,373,601	c. y.	@ $	.45	$	618,120 45
Rip Rap	26,875	c. y.	@	1.00		26,875 00
Total					$	644,995 45

(C) POWER CANAL

CANAL EARTH SECTION						
EARTH EXCAVATION						
Suction Dredge	1,034,979	c. y.	@ $	.45	$	465,740 55
Dipper Dredge	330,000	c. y.	@	.80		264,000 00
Steam Shovel	696,523	c. y.	@	1.10		766,175 30
Rock Excavation	79,016	c. y.	@	3.50		276,556 00
Rock Lining	24,940	c. y.	@	.15		3,741 00
Concrete	29,563	c. y.	@	14.00		413,882 00
Total					$	2,190,094 85
CONTROL WORKS						
Rock Excavation	430	c. y.	@	5.50	$	2,365 00
Concrete, reinforced	1,828	c. y.	@	40.00		73,120 00
Gate with Rollers, Steel	240,800	lbs.	@	.10		24,080 00
Gate Operating Machinery	107,500	lbs.	@	.40		43,000 00
Bridge over Canal						25,000 00
Total					$	167,565 00

CANAL ROCK SECTION					
Earth Excavation	3,011,036	c. y. @	1.10		3,312,139 60
Rock Excavation	2,939,365	c. y. @	3.50		10,387,777 50
Rock Fill	1,149,498	c. y. @	.15		172,424 70
Concrete in Walls	50,525	c. y. @	14.00		707,350 00
Concrete in Lining	285,090	c. y. @	14.00		3,991,260 00
Concrete in Whirlpool	54,610	c. y. @	14.00		764,540 00
Anchor Rods, Steel	681,550	lbs. @	.20		136,310 00
Total					$ 19,371,801 80
ICE CHUTE					
Open Cut Rock Excavation	64,500	c. y. @	5.50		354,750 00
Concrete, plain	1,290	c. y. @	20.00		25,800 00
Concrete, reinforced	1,720	c. y. @	40.00		68,800 00
Gates and Rigs					50,000 00
Total					$ 499,350 00
TESTING OF WHIRLPOOL SECTION					
Concrete, plain	630	c. y. @	20.00		12,600 00
Earth Fill	21,500	c. y. @	.60		12,900 00
Pumping					10,000 00
Total					$ 35,500 00
Canal Earth Section					$ 2,190,094 85
Control Works					167,565 00
Canal Rock Section					19,371,801 80
Ice Chute					499,350 00
Testing of Whirlpool Section					35,500 00
Total Canal					$ 22,264,311 65

(D) FOREBAY

Earth Excavation					Completed
Rock Excavation					Completed
Concrete Lining	23,220	c. y. @	$ 14.00		$ 325,080 00
Concrete Walls	3,978	c. y. @	14.00		55,692 00
Anchor Rods, Steel	23,650	lbs. @	.20		4,730 00
Alterations in Design					225,000 00
Total					$ 610,502 00

(E) SCREEN HOUSE

SUBSTRUCTURE					
Earth Excavation					Completed
Rock Excavation					Completed
Concrete, reinforced	26,810	c. y. @	$ 40.00		$ 1,072,400 00
Structural Steel in Racks	323,575	lbs. @	.075		24,268 13
Structural Steel in Gates	1,088,233	lbs. @	.075		81,617 48
Cast Iron Gate Seats					10,000 00
Ice Chute Gate and Rig					25,000 00
Rock Fill	5,483	c. y. @	1.50		8,224 50
Earth Fill	5,052	c. y. @	3.00		15,156 00
Superstructure					237,405 00
Miscellaneous					75,000 00
Total					$ 1,549,071 11

(F) PENSTOCKS

Tunnel Rock Excavation	6,450	c. y. @	$ 10.00		$ 64,500 00
Open Cut Rock Excavation	25,263	c. y. @	3.50		88,420 50
Concrete, plain	15,588	c. y. @	16.00		249,408 00
Concrete, reinforced	2,795	c. y. @	40.00		111,800 00
Structural Steel	5,535,712	lbs. @	0.1125		622,767 60
Rip Rap Wall	12,363	c. y. @	3.00		37,089 00
Total					$ 1,173,985 10

(G) POWER HOUSE

COFFERDAM					
Concrete, plain	4,085	c. y. @	$ 15.00		$ 61,275 00
Pumping					15,000 00
Removal Charges					45,956 00
SUBSTRUCTURE					
Rock Excavation	298,689	c. y. @	3.50		1,045,411 50
Concrete, reinforced	59,125	c. y. @	32.00		1,892,000 00
Tail Race Excavation	13,975	c. y. @	5.50		76,862 50
Superstructure					1,579,500 00
Miscellaneous					200,000 00
Emergency Fund					200,000 00
Total					$ 5,116,005 00

(H) HYDRAULIC EQUIPMENT

Complete, F.O.B. Queenston					$ 1,829,840 94
Storage, Transportation, Erection..	3,000	tons @	$ 60.00		180,000 00
Total					$ 2,009,840 94

(I) ELECTRICAL EQUIPMENT

Complete in Place	$ 4,752,160 00

(J) RIGHT OF WAY

Acquired

(K) BRIDGE

$ 1,534,023 82

SUMMARY

(A)	INTAKE	$ 581,640 00
(B)	WELLAND RIVER	644,995 45
(C)	POWER CANAL	22,264,311 65
(D)	FOREBAY	610,502 00
(E)	SCREEN HOUSE	1,549,071 11
(F)	PENSTOCKS	1,173,985 10
(G)	POWER HOUSE	5,116,005 00
(H)	HYDRAULIC EQUIPMENT	2,009,840 94
(I)	ELECTRICAL EQUIPMENT	4,752,160 00
(J)	RIGHT OF WAY	Completed
(K)	BRIDGES	1,534,023 82
Total		$ 40,236,535 07
ENGINEERING AND OVERHEAD 8%		3,218,922 81
Total		$ 43,455,457 88
INTEREST CHARGES		
Interest at 6½% per annum, compounded semi-annually		3,407,434 24
Total		$ 46,862,892 12
TOTAL DISBURSEMENTS		
To May 1st, 1920, plus interest compounded annually to January 1st, 1923		14,000,000 00
GRAND TOTAL		$ 60,862,892 12

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate II-C-9

(A) INTAKE

Excavation					
Earth for Piers	18,275	c. y. @	.65	$	11,878 75
Dredging	80,625	c. y. @	.45		36,281 25
Piers					
First Cost of Caissons					40,000 00
Installation of Caissons	each		$3,000.00		111,000 00
Concrete, plain	7,955	c. y. @	15.00		119,325 00
Grillage	215	M FBM	120.00		25,800 00
Booms					
Concrete, reinforced	5,237	c. y. @	40.00		209,480 00
Pontoons					
Structural Steel	268,750	lbs. @	.10		26,875 00
Painting					1,000 00
Total				$	581,640 00

(B) WELLAND RIVER

Earth Excavation	2,541,073	c. y. @	$ .45	$	1,143,482 85
Rip Rap	26,875	c. y. @	1.00		26,875 00
Total				$	1,170,357 85

(C) POWER CANAL

Canal Earth Section					
Earth Excavation					
Suction Dredge	1,552,470	c. y. @	.45	$	698,611 50
Dipper Dredge	330,000	c. y. @	.80		264,000 00
Steam Shovel	696,523	c. y. @	1.10		766,175 30
Rock Excavation	79,016	c. y. @	3.50		266,556 00
Rock Lining	24,940	c. y. @	.15		3,741 00
Concrete	29,563	c. y. @	14.00		413,882 00
Total				$	2,412,965 80
Control Works					
Rock Excavation	430	c. y. @	5.50		2,365 00
Concrete, reinforced	1,828	c. y. @	40.00		73,120 00
Gate with Rollers, Steel	240,800	lbs. @	.10		24,080 00
Gate Operating Machinery	107,500	lbs. @	.40		43,000 00
Bridge over Canal					25,000 00
Total				$	167,565 00
Canal Rock Section					
Earth Excavation	3,011,036	c. y. @	1.10		3,312,139 60
Rock Excavation	2,939,365	c. y. @	3.50		10,287,777 50
Rock Fill	1,149,498	c. y. @	.15		172,424 70
Concrete in Walls	50,525	c. y. @	14.00		707,350 00
Concrete in Lining	285,090	c. y. @	14.00		3,991,260 00
Concrete in Whirlpool	54,610	c. y. @	14.00		764,540 00
Anchor Rods, Steel	681,550	lbs. @	.20		136,310 00
Total				$	19,371,801 80
Ice Chute					
Open Cut Rock Excavation	64,500	c. y. @	5.50		354,750 00
Concrete, plain	1,290	c. y. @	20.00		25,800 00
Concrete, reinforced	1,720	c. y. @	40.00		68,800 00
Gates and Rigs					50,000 00
Total				$	499,350 00

TESTING OF WHIRLPOOL					
Section					
Concrete, plain	630	c. y. @	20.00		12,600 00
Earth Fill	21,500	c. y. @	.60		12,900 00
Pumping					10,000 00
Total				$	35,500 00
Canal Earth Section				$	2,412,965 80
Control Works					167,565 00
Canal Rock Section					19,371,801 80
Ice Chute					499,350 00
Testing Whirlpool Section					35,500 00
Total Canal				$	22,487,182 60

(D) FOREBAY

Earth Excavation				Completed	
Rock Excavation				Completed	
Concrete Lining	23,220	c. y. @	14.00		325,080 00
Concrete Walls	3,978	c. y. @	14.00		55,692 00
Anchor Rods, Steel	23,650	lbs. @	.20		4,730 00
Alterations in Design					225,000 00
Total					610,502 00

(E) SCREEN HOUSE

SUBSTRUCTURE					
Earth Excavation				Completed	
Rock Excavation				Completed	
Concrete, reinforced	26,810	c. y. @	40.00	$	1,072,400 00
Structural Steel in Racks	323,575	lbs. @	.075		24,268 13
Structural Steel in Gates	1,088,233	lbs. @	.075		81,617 48
Cast Iron Gate Seats					10,000 00
Ice Chute Gate and Rig					25,000 00
Rock Fill	5,483	c. y. @	1.50		8,224 50
Earth Fill	5,052	c. y. @	3.00		15,156 00
Superstructure					406,980 00
Miscellaneous					100,000 00
Total					$1,743,646 11

(F) PENSTOCKS

Tunnel Rock Excavation	11,126	c. y. @	10.00	$	111,260 00
Open Cut Rock	35,475	c. y. @	3.50		124,162 50
Concrete, plain	26,875	c. y. @	16.00		430,000 00
Concrete, reinforced	2,795	c. y. @	40.00		111,800 00
Structural Steel	9,226,187	lbs. @	.1125		1,037,946 04
Rip Rap, Wall	19,135	c. y. @	3.00		57,405 00
Total				$	1,872,573 54

(G) POWER HOUSE

COFFERDAM					
Concrete, plain	6,880	c. y. @	15.00	$	103,200 00
Pumping					25,000 00
Removal Charges					77,400 00
SUBSTRUCTURE					
Rock Excavation	375,014	c. y. @	3.50		1,312,549 00
Concrete, reinforced	99,975	c. y. @	32.00		3,199,200 00
Tail Race Excavation	23,650	c. y. @	5.50		130,075 00
Superstructure					2,673,000 00
Miscellaneous					250,000 00
Emergency Fund					250,000 00
Total				$	8,020,424 00

(H) HYDRAULIC EQUIPMENT

Complete F.O.B. Queenston	$ 3,557,000 94
Storage, Transportation, Erection, ...5,400 tons @ 60.00	324,000 00
Total	$ 3,557,000 94

(I) ELECTRICAL EQUIPMENT

Complete in Place	$ 8,417,360 00

(J) RIGHT OF WAY

Acquired

(K) BRIDGES

$ 1,534,023 82

SUMMARY

(A) INTAKE	$ 581,640 00
(B) WELLAND RIVER	1,170,357 85
(C) POWER CANAL	22,487,182 60
(D) FOREBAY	610,502 00
(E) SCREEN HOUSE	1,743,646 11
(F) PENSTOCKS	1,872,573 54
(G) POWER HOUSE	8,020,424 00
(H) HYDRAULIC EQUIPMENT	3,557,000 94
(I) ELECTRICAL EQUIPMENT	8,417,360 00
(J) RIGHT OF WAY	Completed
(K) BRIDGES	1,534,023 82
Total	$ 49,994,710 86
ENGINEERING AND OVERHEAD 8 per cent.	3,999,576 87
Total	$53,994,287 73
INTEREST CHARGES	
Interest at 6½% per annum compounded semi-annually	4,222,347 72
Total	$ 58,216,635 45
TOTAL DISBURSEMENTS	
To May 1, 1920, plus interest compounded annually to January 1, 1923	$ 14,000,000 00
GRAND TOTAL	$ 72,216,635 45

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate III-C-6

(A) INTAKE

EXCAVATION	
Earth for Piers .....21,500 c. y. @ .65	$ 13,975 00
Dredging .....104,275 c. y. @ .45	46,923 75
PIERS	
First Cost of Caissons	40,000,000 00
Installation of Caissons .....each $3,000.00	111,000 00
Concrete, plain .....8,600 c. y. @ 15.00	129,000 00
Grillage .....215 M FBM 120.00	25,800 00
BOOMS	
Concrete, reinforced .....5,237 c. y. @ 40.00	209,480 00
PONTOONS	
Structural Steel .....268,750 lbs. @ .10	26,875 00
Painting	1,000 00
Total	$ 604,053 75

(B) WELLAND RIVER

Earth Excavation	2,804,881	c. y. @	.45	$	1,262,196 45
Rip Rap	26,875	c. y. @	1.00		26,875 00
Total				$	1,289,071 45

(C) POWER CANAL

CANAL EARTH SECTION					
Earth Excavation					
Suction Dredge	1,498,495	c. y. @	.45	$	674,322 75
Dipper Dredge	330,000	c. y. @	.80		264,000 00
Steam Shovel	696,523	c. y. @	1.10		766,175 30
Rock Excavation	175,977	c. y. @	3.50		615,919 50
Rock Lining	27,413	c. y. @	.15		4,111 95
Concrete	32,250	c. y. @	14.00		451,500 00
Total				$	2,776,029 50
CONTROL WORKS					
Rock Excavation	457	c. y. @	5.50		2,513 50
Concrete, reinforced	1,881	c. y. @	40.00		75,240 00
Gate with Rollers, Steel	322,500	lbs. @	.10		32,250 00
Gate Oper. Machinery	139,750	lbs. @	.40		55,900 00
Bridge over Canal					25,000 00
Total				$	190,903 50
CANAL ROCK SECTION					
Earth Excavation	3,011,035	c. y. @	1.10		3,312,138 50
Rock Excavation	130,494	c. y. @	5.50		717,717 00
Rock Excavation	3,442,258	c. y. @	3.50		12,047,903 00
Rock Fill	244,025	c. y. @	.15		36,603 75
Concrete in Walls	50,525	c. y. @	14.00		707,350 00
Concrete in Lining	307,235	c. y. @	14.00		4,301,290 00
Concrete in Whirlpool	61,598	c. y. @	14.00		862,372 00
Anchor Rods, Steel	943,850	lbs. @	.20		188,770 00
Total				$	22,174,144 25
ICE CHUTE					
Open Cut Rock Exc.	64,500	c. y. @	5.50		354,750 00
Concrete, plain	1,290	c. y. @	20.00		25,800 00
Concrete, reinforced	1,720	c. y. @	40.00		68,800 00
Gates and Rigs					50,000 00
Total				$	499,350 00
TESTING OF WHIRLPOOL SECTION					
Concrete, plain	788	c. y. @	20.00		15,760 00
Earth Fill	32,358	c. y. @	.60		19,414 80
Pumping					10,000 00
Total				$	45,174 80
Canal Earth Section				$	2,776,029 50
Control Works					190,903 50
Canal Rock Section					22,174,144 25
Ice Chute					499,350 00
Testing of Whirlpool Section					45,174 80
Total Canal				$	25,685,602 05

(D) FOREBAY

Earth Excavation	29,025	c. y. @	1.10	$	31,927 50
Rock Excavation	239,725	c. y. @	3.50		829,037 50
Rock Excavation	145,125	c. y. @	5.50		798,187 50
Concrete Lining	34,905	c. y. @	14.00		488,670 00
Concrete Walls	4,300	c. y. @	14.00		60,200 00
Anchor Rods, Steel	33,863	lbs. @	.20		6,772 60
Alterations in Design					225,000 00
Total				$	604,053 75

(E) SCREEN HOUSE

SUBSTRUCTURE					
Earth Excavation	3,600	c. y. @	1.10	$	3,960 00
Rock Excavation	14,050	c. y. @	3.50		49,175 00
Concrete, reinforced	38,808	c. y. @	40.00		1,552,320 00
Structural Steel in Racks	430,000	lbs. @	.075		32,250 00
Structural Steel in Gates	1,451,250	c. y. @	.075		108,843 75
Cast Iron Gate Seats					14,000 00
Ice Chute Gate and Rig					25,000 00
Rock Fill	7,848	c. y. @	1.50		11,772 00
Earth Fill	6,934	c. y. @	3.00		20,802 00
Superstructure					285,000 00
Miscellaneous					90,000 00
Total				$	2,193,122 75

(F) PENSTOCKS

Tunnel Rock Excavation	7,633	c. y. @	10.00	$	76,330 00
Open Cut Rock Excavation	24,403	c. y. @	3.50		85,410 50
Concrete, plain	18,490	c. y. @	16.00		295,840 00
Concrete, reinforced	3,763	c. y. @	40.00		150,520 00
Structural Steel	6,353,250	lbs. @	.1125		714,740 63
Rip Rap	13,975	c. y. @	3.00		41,925 00
Total				$	1,364,766 13

Acquired

(G) POWER HOUSE

COFFERDAM					
Concrete, plain	5,160	c. y. @	15.00	$	77,400 00
Pumping					20,000 00
Removal Charges					58,050 00
SUBSTRUCTURE					
Rock Excavation	407,963	c. y. @	3.50		1,427,870 50
Concrete, reinforced	67,725	c. y. @	32.00		2,167,200 00
Tail Race Excavation	17,200	c. y. @	5.50		94,600 00
Superstructure					1,850,000 00
Miscellaneous					215,000 00
Emergency Fund					215,000 00
Total				$	6,125,120 50

(H) HYDRAULIC EQUIPMENT

Complete F.O.B. Queenston				$	2,218,040 00
Storage, Transportation, Erection	3,600	tons @	60.00		216,000.00
Total				$	2,434,040 00

(I) ELECTRICAL EQUIPMENT

Complete in Place	$	5,668,460 00

(J) RIGHT OF WAY

Acquired

(K) BRIDGES

SUMMARY

(A) INTAKE	$	604,053 75
(B) WELLAND RIVER		1,289,071 45
(C) POWER CANAL		25,685,602 05
(D) FOREBAY		2,449,795 10
(E) SCREEN HOUSE		2,193,122 75
(F) PENSTOCKS		1,364,766 13
(G) POWER HOUSE		6,125,120 50
(H) HYDRAULIC EQUIPMENT		2,434,040 00
(I) ELECTRICAL EQUIPMENT		5,668,460 00
(J) RIGHT OF WAY		Completed
(K) BRIDGE		1,534,023 82
Total	$	49,348,055 55

ENGINEERING AND OVERHEAD 8 per cent.	$ 3,947,844 44
Total	$ 53,295,899 99
INTEREST CHARGES	
Interest at 6½% per annum compounded semi-annually	4,692,726 74
Total	$ 57,988,626 73
TOTAL DISBURSEMENTS	
To May 1, 1920, plus interest compounded annually to January 1, 1923	14,000,000 00
GRAND TOTAL	$71,988,626 73

Niagara Development

Hydro-Electric Power Commission of Ontario

Estimate III-C-12

(A) INTAKE

EXCAVATION					
Earth for Piers	21,500	c. y. @	.65	$	13,975 00
Dredging	104,275	c. y. @	.45		46,923 75
PIERS					
First Cost of Caissons					40,000 00
Installation of Caissons	each		$3,000		111,000 00
Concrete, plain	8,600	c. y. @	15.00		129,999 00
Grillage	215	M. FBM	120.00		25,800 00
BOOMS					
Concrete, reinforced	5,237	c. y. @	40.00		209,480 00
PONTOONS					
Structural Steel	268,750	lbs. @	.10		26,875 00
Painting					1,000 00
Total				$	604,053 75

(B) WELLAND RIVER

Earth Excavation	4,207,323	c. y. @	.45	$	1,893,295 35
Rip Rap	26,875	c. y. @	1.00		26,875 00
Total				$	1,920,170 35

(C) POWER CANAL

CANAL EARTH SECTION					
Earth Excavation					
Suction Dredge	2,247,742	c. y. @	.45	$	1,011,483 90
Dipper Dredge	330,000	c, y. @	.80		264,000 00
Steam Shovel	696,523	c. y. @	1.10		766,175 30
Rock Excavation	175,977	c. y. @	3.50		615,919 50
Rock Lining	27,413	c. y. @	.15		4,111 95
Concrete	32,250	c. y. @	14.00		451,500 00
CONTROL WORKS					
Total				$	3,113,190 65
Rock Excavation	457	c. y. @	5.50		2,513 50
Concrete, reinforced	1,1881	c. y. @	40.00		75,240 00
Gate with Rollers, Steel	322,500	lbs. @	.10		32,250 00
Gate Operating Machinery	139,750	lbs. @	.40		55,900 00
Bridge over Canal					25,000 00
Total				$	190,903 50
CANAL ROCK SECTION					
Earth Excavation	3,011,035	c. y. @	1.10	$	3,312,138 50
Rock Excavation	130,494	c. y. @	5.50		717,717 00
Rock Excavation	3,442,258	c. y. @	3.50		12,047,903 00
Rock Fill	244,025	c. y. @	.15		36,603 75

Concrete in Walls	50,525	c. y.	@	14.00	707,350 00
Concrete in Lining	307,235	c. y.	@	14.00	4,301,290 00
Concrete in Whirlpool	61,598	c. y.	@	14.00	862,372 00
Anchor Rods, Steel	943,850	lbs.	@	.20	188,770 00
Total					$ 22,174,144 25
ICE CHUTE					
Open Cut Rock Excavation	64,500	c. y.	@	5.50	$ 354,750 00
Concrete, plain	1,290	c. y.	@	20.00	25,800 00
Concrete, reinforced	1,720	c. y.	@	40.00	68,800 00
Gates and Rigs					50,000 00
Total					$ 499,350 00
TEST OF WHIRLPOOL SECTION					
Concrete, plain	788	c. y.	@	20.00	$ 15,760 00
Earth Fill	32,358	c. y.	@	.60	19,414 80
Pumping					10,000 00
Total					$ 45,174 80
Canal Earth Section					$ 3,113,190 65
Control Works					190,903 50
Canal Rock Section					22,174,144 25
Ice Chute					499,350 00
Testing of Whirlpool Section					45,174 80
Total Canal					$ 26,022,763 20

(D) FOREBAY

Earth Excavation	29,025	c. y.	@	1.10	$ 31,927 50
Rock Excavation	239,725	c. y.	@	3.50	839,037 50
Rock Excavation	145,125	c. y.	@	5.50	798,187 50
Concrete Lining	34,905	c. y.	@	14.00	488,670 00
Concrete Walls	4,300	c. y.	@	14.00	60,200 00
Anchor Rods, Steel	33,863	lbs.	@	.20	6,772 60
Alterations in Design					225,000 00
Total					$ 2,449,795 10

(E) SCREEN HOUSE

SUBSTRUCTURE					
Earth Excavation	3,600	c. y.	@	1.10	$ 3,960 00
Rock Excavation	14,050	c. y.	@	3.50	49,175 00
Concrete, reinforced	38,808	c. y.	@	40.00	1,552,320 00
Structural Steel in Racks	430,000	lbs.	@	.075	32,250 00
Structural Steel in Gates	1,451,250	lbs.	@	.075	108,843 75
Cast Iron Gate Seats					14,000 00
Ice Chute Gate and Rig					50,000 00
Rock Fill	7,848	c. y.	@	1.50	11,772 00
Earth Fill	6,934	c. y.	@	3.00	20,802 00
Superstructure					525,000 00
Miscellaneous					125,000 00
Total					$ 2,493,122 75

(F) PENSTOCKS

Tunnel Rock Excavation	15,050	c. y.	@	10.00	$ 150,500 00
Open Cut Rock	47,945	c. y.	@	3.50	167,807 50
Concrete, plain	36,335	c. y.	@	16.00	581,360 00
Concrete, reinforced	3,763	c. y.	@	40.00	150,520 00
Structural Steel	12,491,500	lbs.	@	.1125	1,405,293 75
Rip Rap, Wall	26,123	c. y.	@	3.00	78,369 00
Total					$ 2,533,850 25

(G) POWER HOUSE

COFFERDAM					
Concrete, plain	8,708	c. y.	@	15.00	$ 130,620 00
Pumping					35,000 00

Removal Charges				97,965 00
SUBSTRUCTURE				
Rock Excavation	522,289	c. y. @	3.50	1,828,011 50
Concrete, reinforced	131,688	c. y. @	32.00	4,214,016 00
Tail Race Excavation	32,250	c. y. @	5.50	177,375 00
Superstructure				3,500,000 00
Miscellaneous				300,000 00
Emergency Fund				300,000 00
Total				$ 10,582,987 50

(H) HYDRAULIC EQUIPMENT

Complete F.O.B. Queenston				$ 4,322,780 00
Storage, Transportation, Erection	7,200 tons	@	60.00	432,000 00
Total				$ 4,754,780 00

(I) ELECTRICAL EQUIPMENT

Complete in place	$ 11,166,260 00

(J) RIGHT OF WAY

Acquired

(K) BRIDGES

$ 1,534,023 82

SUMMARY

(A) INTAKE	$ 604,053 75
(B) WELLAND RIVER	1,920,170 35
(C) POWER CANAL	26,022,763 20
(D) FOREBAY	2,449,795 10
(E) SCREEN HOUSE	2,493,122 75
(F) PENSTOCKS	2,533,850 25
(G) POWER HOUSE	10,582,987 50
(H) HYDRAULIC EQUIPMENT	4,754,780 00
(I) ELECTRICAL EQUIPMENT	11,166,260 00
(J) RIGHT OF WAY	Completed
(K) BRIDGES	1,534,023 82
Total	$ 64,061,806 72
ENGINEERING AND OVERHEAD 8 per cent.	5,124,944 54
Total	$ 69,186,751 26
INTEREST CHARGES	
Interest at 6½% per annum compounded semi-annually	5,743,755 42
Total	$ 74,930,506 68
TOTAL DISBURSEMENTS	
To May 1st, 1920, plus interest compounded annually to January 1st, 1923	14,000,000 00
GRAND TOTAL	$ 88,930,506 68

CORRESPONDENCE

OF

HUGH L. COOPER AND CO.

101 Park Ave.
New York

-RE-

QUEENSTON-CHIPPAWA DEVELOPMENT

July 6, 1920.

Hugh L. Cooper & Co.,

101 Park Ave.,
New York, N. Y.,
May 1, 1920.

Mr. H. G. Acres,
Hydro-Electric Commission,
190 University Ave.,
Toronto, Canada.

Dear Sir:—

With respect to the engineering work that we are to perform for you relating to your Chippawa plant, it will be well at this time to convey to you our understanding of the scope of this work in order that you may either approve this understanding or modify it as you desire. We are to make an examination and report on the project as follows:

1. We are to report on the capacity of the canal, intake system, forebay and penstocks, and power house, having in mind also such future changes of levels at the intake as will probably result from modifications of the present treaty between Great Britain and the United States regarding the final quantity of water that may be diverted at Niagara Falls for power purposes. Under this instruction we will express our views as to the practicability of the design you are building and its efficiency for the best use of 15,000 c.f.s. of water plus a minor allowance of 500 c.f.s. for debris disposal.

2. We are to make a general check as to the strength and suitability of all the permanent structures enumerated in No. 1.

3. We are to make such general surveys and measurements as will enable us to check your regular monthly estimates as to the accuracy and as to the amount of completed work on permanent structures at the time of our report. The extent of these measurements will be limited to the amount of work we find necessary to enable us to make a safe certificate respecting the same.

4. We are to make a general report on the construction organization which report will include comments on the handling of the work up to date and recommendations as to the installation of additional machinery for the balance of the work, having in view the present high costs of labor and materials.

5. We are to make an estimate of the time that will probably be required to place one unit and five units in commercial operation.

6. We are to make an estimate as to the amount of money that will be needed to complete the plant up to five unit basis, and we will be guided in this estimate by the results obtained from Paragraph 3.

7. We are to make such general investigations of your accounting system as to enable us to certify as to its efficiency and reliability.

8. In making up our cost estimates we will use your figures for the cost of all real estate required.

Would you kindly advise me here as to the correctness of the foregoing at your convenience and oblige.

Yours very truly,
(Signed) Hugh L. Cooper.

APPENDIX "D"

Appendix "D" in the original report consists of prints of the following plans and drawings, etc., prepared by Hugh L. Cooper & Company, Consulting Engineers, 101 Park Avenue, New York:—

DRAWING NO.	TITLE	DATE
3438	Hydro-Electric Power Commission of Ontario; Chippawa Hydro-Electric Project, location Map.	August 16, 1920.
3439	Hydro-Electric Power Commission of Ontario; Chippawa Hydro-Electric Project, Excavation Progress Chart of May 1st, 1920.	August 16, 1920.
3440	Hydro-Electric Power Commission of Ontario; Chippawa Hydro-Electric Project. Chart showing comparative cost of ultimate installations.	August 16, 1920.
3441	Hydro-Electric Power Commission of Ontario; Chippawa Hydro-Electric Project. Drawing showing comparative cost of initial installations.	August 16, 1920.

Hugh L. Cooper & Co.,
101 Park Avenue,
New York.

July 6, 1920.

Sir Adam Beck, Chairman,
Hydro-Electric Power Commission,
Toronto, Canada.

Sir:—

With respect to the probable time when two units of the Chippawa plant can be made available for commercial operation.

You have given me a complete outline of your future construction program and with this program I am in accord. If you carry out this program you should have the two Wellman-Seaver-Morgan units (50,000 H.P. each) ready for commercial operation October 1st, 1921.

With respect to the probable cost of the works as now designed we are in substantial agreement with the figures you have recently submitted to the Provincial Government.

Yours truly,
Hugh L. Cooper & Co. (*typed*)

New York.

October 4, 1920.

Col. Sir Adam Beck,
Chairman, Hydro-Electric Power commission,
Toronto, Canada.

Dear Sir:—

On September 16th you advised me to withhold the filing of our final report until after a final conference was held between the undersigned and your engineers and certain arbitrators, not named, whom you proposed to call in, all for the purpose of making an attempt to harmonize the differences in the engineering views held by the undersigned and the engineers of the Hydro-Electric Power Commission.

It was my understanding that this conference would be held not later than the last of September, and I have been holding myself here in New York for ten days for this work. In order that I may plan my work so that I may be available for this conference, will you kindly let me know when it is to take place?

Hoping, as I do, that this meeting will be of great benefit to the Province of Ontario, I trust you will not misunderstand my urgency when I request you to have the conference at as early a date as possible, and have stenographic records kept of all the views expressed at that time.

Very truly yours,
(*Sgd.*) Hugh L. Cooper.

Hugh L. Cooper & Co.,
101 Park Avenue,
New York.

Mr. W. R. Pope, Secretary,
Hydro-Electric Power Commission,
190 University Ave.,
Toronto, Canada.

Dear Sir:—

We beg to hand you herewith by special messenger three complete copies of our final report on your Chippawa project.

Yours very truly,
(*Sgd.*) Hugh L. Cooper & Co.

Hugh L. Cooper & Co.,
101 Park Avenue,
New York.

May 1, 1920.

Mr. H. G. Acres,
Hydro-Electric Commission,
190 University Ave.,
Toronto, Canada.

Dear Sir:—

With respect to the engineering work that we are to perform for you relating to your Chippawa plant, it will be well at this time to convey to you our understanding of the scope of this work in order that you may either approve this understanding or modify it as you desire. We are to make an examination and report on the project as follows:

1. We are to report on the capacity of the canal, intake system, forebay and penstocks, and power house, having in mind also such future changes of levels at the intake as will probably result from modifications of the present treaty between Great Britain and the United States regarding the final quantity of water that may be diverted at Niagara Falls for power purposes. Under this instruction we will express our views as to the practicability of the design you are building and its efficiency for the best use of 15,000 c.f.s. of water plus a minor allowance of 500 c.f.s. for debris disposal.
2. We are to make a general check as to the strength and suitability of all the permanent structures enumerated in No. 1.
3. We are to make such general surveys and measurements as will enable us to check your regular monthly estimates as to the accuracy and as to the amount of completed work on permanent structures at the time of our report. The extent of these measurements will be limited to the amount of work we find necessary to enable us to make a safe certificate respecting the same.
4. We are to make a general report on the construction organization which report will include comments on the handling of the work up to date and recommendations as to the installation of additional machinery for the balance of the work, having in view the present high costs of labor and materials.
5. We are to make an estimate of the time that will probably be required to place one unit and five units in commerical operation.
6. We are to make an estimate as to the amount of money that will be needed to complete the plant up to five unit basis, and we will be guided in this estimate by the results obtained from Paragraph 3.
7. We are to make such general investigations of your accounting system as to enable us to certify as to its efficiency and reliability.
8. In making up our cost estimates we will use your figures for the cost of all real estate required.

Will you kindly advise me here as to the correctness of the foregoing at your convenience and oblige.

Yours very truly,

(*Sgd.*) Hugh L. Cooper.

REPORT OF

FRANCIS LEE STUART

AND

REPORT OF

H. S. KERBAUGH

-RE-

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

September 30, 1920

FRANCIS LEE STUART,
Consulting Engineer,
50 East 42nd Street

September 30, 1920.

SIR ADAM BECK, Chairman,
Hydro-Electric Power Commission,
190 University Avenue,
Toronto, Ontario.

Dear Sir:

We submit herewith our joint report on the Chippawa-Queenston Development, on the Niagara River, as of September 30, 1920, and also enclose you our individual bills.

Yours truly,
(Sgd.) FRANCIS LEE STUART.
(Sgd.) H. S. KERBAUGH.

FRANCIS LEE STUART,
Consulting Engineer,
50 East 42nd Street, New York, N.Y.

September 30, 1920.

SIR ADAM BECK, Chairman,
Hydro-Electric Power Commission,
190 University Avenue,
Toronto, Ontario.

Dear Sir:

In compliance with your request that we make an inspection of your construction equipment and methods at Chippawa-Queenston Development on the Niagara River and to advise you of our opinion and conclusions on the following features of the undertaking, to wit:

1st—Suitability of the plant for the construction programme proposed,
2nd—Possible dates of completion of the canal for Generation of Power by the 1st and 2nd units at power house,
3rd—Probable cost to complete;

we have visited the work and in conference with your Engineering and Construction Staff have personally examined into the construction features of the work; have considered details of the equipment, its past performances and suitability for the service required, and given due weight to other features which have bearing on the questions involved, and we report to you as follows:

INTAKE

To provide maximum protection, duplicate intakes of widely different characteristics are planned; each of these to be operated independently and either capable of supplying the canal with water up to 15,000 c.f.s. The plans provide for the construction of an improved boom type of intake with adjustable gates, supplemented by the addition of pipe intakes to work independently or as auxiliary intakes for improving the performance of the boom intake during the worst winter conditions in the Niagara River.

These auxiliary intakes have been designed and tested out in model forms by members of your staff familiar with winter conditions in the Niagara River and in our opinion their reasoning and conclusions from the model tests warrant the proposed type of construction.

We find dredging work for this section well under way and that the boom section of the intake is scheduled for completion in the Fall of 1921, before ice begins to form. The construction of the intake is not a controlling factor in any of the schedules of completion of the work, as enough water can be drawn through the lower channel around Hogg Island for the 1st and 2nd Turbine Units, without interference with the completion of, or help from, the intake proper.

WELLAND RIVER SECTION.

This work is not a governing feature of the proposed schedule. There is at present flow area enough in this portion of the Welland River to provide the power canal with enough water for the 1st and 2nd Units. The work of enlarging this section of the River, for 15,000 c.f.s., can proceed as needed for commercial requirements, and such enlargement can be made by the present cable equipment now in use until dredge equipment is available.

GATE HOUSE.

There are 25,000 cu. yds. of concrete to place, some of which could be placed this fall and the balance after March 15, 1921, completing by the end of July, 1921.

PENSTOCKS.

Penstocks have been contracted for, completely erected by June 1st, 1921, and we see no reason why such schedule cannot be maintained.

POWER HOUSE.

The schedule provides for Ice Run, Service Gates, No. 1 Unit complete, and part of No. 2 Unit complete. Excavation for Power House will be complete October 15, 1920. 15,000 cu. yds. of concrete should be in place for start of erection of two units, No. 1 and No. 2, December 20th, 1920. It is expected to start concreting September 25th, and place the necessary amount by December 1st.

The scroll case of No. 1 Unit should be erected by January 1st. After the erection of this scroll case, a similar scroll case for Unit No. 2 should be erected and then about 10,000 cu. yds. of concrete placed in both scroll cases, in the Spring of 1921.

The erecting bay will be ready December 1st. The first generator is to be ready for shipment December 1st, 1920, and it will take four months for erection after arrival—say erected by May 15th. In the meantime the erection of the turbine and placing of concrete around the scroll case will have been completed.

POWER CANAL.

The construction of power canal section from the Welland River to the Gate House at north end of canal requires the excavating of 4,760,000 cu. yds. of earth; 2,669,000 cu. yds. of rock and placing of 200,000 cu. yds. of concrete lining and 120,000 cu. yds. of concrete walls, etc.

For purposes of this report this section can be sub-divided into three divisions:

1st—From Welland River to M.C.R.R. Bridge, Sta. O, to Sta. 10, exclusively an earth section.

2nd—From M.C.R.R. Bridge Sta. 10 to Control Works Sta. 45, exclusively an earth section.

3rd—From Control Works Sta. 45 to Gate House Sta. 460, which includes all of the rock section of the Canal.

POWER CANAL FROM WELLAND RIVER TO M.C.R.R. BRIDGE.

This work is not a controlling feature of the schedule. There are 326,000 cu. yds. of earth still to excavate for 15,000 c.f.s. The present shovel working in this division should have excavated a cross-section large enough to provide 3,000 c.f.s. required for Units No. 1 and No. 2 early next spring and if necessary a dredge could help finish completing full cross-section for 15,000 c.f.s. by August, 1921.

POWER CANAL FROM M.C.R.R. BRIDGE STA. 10, TO CONTROL WORKS STA. 45.

This division is exclusively one of earth excavation and requires for 3,000 c.f.s. with a velocity of 2½ ft. per second for Units No. 1 and No. 2, the excavation of 900,000 cu. yds. of earth, or for the full cross-section required for 15,000 c.f.s. the excavation of 1,060,000 cu. yds. of earth. For Scheduling effect it is herein considered with the Rock Division from Sta. 10 to Sta. 460.

ROCK SECTION—POWER CANAL FROM CONTROL WORKS STA. 45 TO GATE HOUSE STA. 460.

This Division requires from September 1st, 1920, the excavation of 3,373,600 cu. yds. of earth and 2,669,000 cu. yds. of rock and placing of 40,000 lineal feet of side and bottom lining in the canal, consisting of 200,000 cu. yds. of concrete and 120,000 cu. yds. of concrete in Control Works, Transition Section, and Walls.

It is the controlling feature in the completion of the entire Development for production of power at any given date and the essential requirement of the problem is to entirely complete the rock excavation in the bottom of the cut between Sta. 45 and Sta. 290 in time to permit the completion of the concrete lining by any date fixed for turning the water into the canal.

At the summit near Lundy's Lane the work has an extreme depth of cut of 140 feet of which the bottom 84 feet is solid rock and the balance earth of varying character.

From Sta. 105 to Sta. 240 there is an overburden of 1,861,000 cu. yds. of earth which has to be excavated before the great mass of rock section involved between these stations can be completely covered with plant. Similarly from Sta. 45 to Sta. 105 there is an overburden of earth above the rock of 1,434,000 cu. yds. which has to be moved in time to complete the Rock Section and its lining.

Your organization has prepared a schedule for completion of the power canal, in the same way as the schedules for the other features of the work have been prepared, and we have gone over this programme in detail considering each item of equipment and output estimated.

We find there are now available for the power canal work above, three shovel units of 225-B type, with 8-yard dippers, capable of loading on a track 63 feet above the bottom of its cut, and that two more units of the same type will be in operation in October and November respectively. There are also available three shovel units of 103-C type, with 4-yard dippers, and one Atlantic type, 2½ yard dipper unit.

From past performances of the various units on this work there has been deduced an expected yardage per unit in earth and rock in summer and winter and these factors have been used to schedule the completion of the rock and earth excavation required.

These factors are based on average output per unit and include work delays, etc.

	Double Shift Basis.	
225-B Type, 8 yd. shovel	Earth	120,000
	Rock	60,000
103-C Type, 4 yd. shovel	Earth	80,000
	Rock	35,000
Atlantic Type	Earth	50,000

Using these factors we find the programme to complete entire excavation of earth and rock required so that concrete can be completed in time to turn water in the canal by November 1st, feasible if certain additional cars and locomotives are made to the present plant.

SCHEDULE OF APPROXIMATE OUTPUT OF SHOVELS REQUIRED PER MONTH IN EARTH AND ROCK TO COMPLETE FOR GENERATING POWER NOVEMBER 1, 1921.

	Earth	Rock	Total
	cu. yds.	cu. yds	cu. yds.
September	298,000	82,000	380,000
October	498,000	116,000	614,000
November	628,000	140,000	768,000
December	498,000	140,000	638,000
January	398,000	136,000	534,000
February	308,000	226,000	534,000
March	308,000	226,000	534,000
April	297,000	269,000	566,000
May	248,000	274,000	522,000
June	283,000	266,000	549,000
July	293,000	261,000	554,000
August	293,000	270,000	563,000
September	293,000	270,000	563,000
October	146,000	40,000	186,000
	4,789,000	2,716,000	7,505,000

The concrete schedule of 200,000 cubic yards of lining of canal and 120,000 cubic yards of concrete in Control Works, Transition sections, and Walls, requires a schedule which will place the concrete as close behind the units which excavate the sections to receive the lining as it is practical to work. On account of the lateness of the season most of the concrete will have to be put in in 1921.

The magnitude of the work precludes the work being done with separate mixing units and we approve the plan of central plants for mixing the concrete, with bucket distribution in cars as needed, and recommend the plant as proposed and that all concrete that can be placed this fall be completed to help out next spring's programme.

CRUSHER PLANTS

In special reference to your request that we consider the crushing plant requirements for broken stone for concrete and the possibility of crushing a still larger quantity for the general good of the Province, as cheap stone for highway or other public purposes; we find the rock is an excellent quality of limestone. The expenditure for stripping, blasting, digging, loading into cars, and transportation to a disposal point having been made in the course

of the work of providing the power canal, the cost of actually crushing for other purposes is but a small portion of the cost or value of such stone for public use.

We consider that it would be of great lasting public benefit and profit if all the available stone were crushed and some broad policy adopted on the basis "We will help you if you try to help yourself," by which this cheaply-produced broken stone of the power canal can be made to give an impetus to the "Good Roads" movement, throughout the country roads of the Province of Ontario.

The field of usefulness is a large one by rail distributing of barges loaded from the canal construction tracks near Queenston.

We estimate that it is possible to provide by the conservation methods proposed about 4,600,000 tons of broken stone, which can be sold for public purposes, under current market prices, and yet give the Power Canal a credit from the sale thereof of some $2,600,000.00 and reduce the net cost of the undertaking.

The present crusher plant, with certain small additions, can crush about 2,500 cubic yards per day. We recommend that you have installed another crushing plant of 4,000 cubic yards per day capacity near the centre of your work and in such location that a rock dump can be established for all excess rock excavated that it is not possible to crush without delay to shovels, and which by storing near the crusher plant, can be crushed afterwards as needed with slight additional expense.

PLANT YET TO BE RECEIVED.

Additional Plant proposed and yet to be purchased to carry out schedule discussed herein for production of power Nov. 1st, 1921.

Additional plant required for the two large units now being installed October and November, 1920, for completion November 1st, 1921.

LOCOMOTIVES: On hand and ordered 42; Required 47. To be provided from other work 3, leaving 2 new locomotives to be purchased at $35,000 ..... $70,000.00

CARS: 20-Yard capacity, on hand 280; Required 318, leaving 38 new cars to be purchased at $5,500 ..... 209,000.00

CRUSHER: 1 No. 7½ McCully Crusher delivered and installed for changes to existing crusher plant, moving track back 5 feet and changing slightly, and an additional unloading track—to give 2,500 cubic yards capacity per day 40,000.00

$319,000.00

ADDITIONAL CRUSHER PLANT: We recommend the installation of a complete crusher plant of 4,000 cubic yards per day 350,000.00

TOTAL $669,000.00

EQUIPMENT.

Our inspection of your present equipment and its performance on the work indicates that sound judgment has been used in its selection for the construction involved and particularly so in having provided the 325 ton shovels with 8-yard dippers for work in the canal, and modern standard gauge equipment for transportation needs. The proposed additions to the present equipment are necessary and we recommend their purchase.

ESTIMATE OF COST

With the aid of your staff and based on the cost data of the work, we estimate the cost to complete the power canal and installation of five (5) Hydro-Electric Units 250,000 H.P. and the first stage of the ultimate intake construction as follows.

Section	Cost to Aug. 26, '20	Remaining Cost	Grand Total
1—Intake	$259,578	$1,340,003	$1,599,581
2—Welland River	387,568	974,823	1,362,391
3 and 3A—Canal	7,071,023	16,294,033	23,365,056
4—Forebay	794,154	116,000	910,154
5—Screen House	97,794	976,300	1,074,094
6—Penstocks	38,828	$1,052,310	$1,091,138
7—Power House	437,701	1,560,000	1,997,701
8—Hydraulic Mach'y		1,646,000	1,646,000
9—Right-of-way	1,000,000		1,000,000
Miscellaneous		200,000	200,000
Bridges	909,000	1,091,000	2,000,000
	$10,995,646	$25,250,469	$36,246,115
	Contingencies 10%		3,624,611
		Total Net Cost	39,870,726
Estimate of Cost of Superstructure and Electrical Equipment up to L.T. Bus			5,301,033
Estimated residue value of Plant and Stores on hand to finish			4,700,000
		Total Investment	$49,871,759
Less: Possible Salvage Recoverable		$4,000,000	
Receipts from Broken Stone		2,600,000	6,600,000
		Total Net Investment	$43,271,759
		Total Cost per H.P.	$ 173.08

The ultimate capacity of present plans contemplates the full use of 15,000 c.f.s., and the installation of a total of nine (9) Units producing 450,000 H.P., and will require when installed, $9,000,000 additional capital, making a total estimated cost of $52,271,759.00

Total Cost per H.P. 116.16

In the above estimate we have generally figured on basic prices of earth excavation 70c. per cu. yd.; rock excavation $2.70 per cu. yd.; plain concrete $14.50 per cu. yd.; and reinforced concrete $25.00 per cu. yd.

NOTES: Total expenditure to end of August, 1920, is $23,268,067.93. Of this total $10,995,646.00 is shown above as being the actual total cost to August 26, 1920, of the permanent work done on the project. This cost carries its full proportion of charges including interest, plant, depreciation and general overhead.

The balance of the total expenditure to end of August, 1920, amounting to $12,272,421.93, is partly included in the items making up the remaining

costs of $25,250,469.00 and partly in the item of $5,301,033.00 making up the cost of superstructure and electrical equipment, and finally in the estimate on Sheet 10 following, covering the total cost of the ultimate installation.

SCHEDULED FOR COMPLETION SEPT 1st., 1921.

In reply to your enquiry as to possibility of generating current Sept. 1st, 1921, we find that with the plant provided and proposed for completion Nov. 1st, 1921, and a further addition of 21" hydraulic Dredge Unit to begin work by or before Jan. 1st, 1921, it is feasible to generate power by Sept. 1st, 1921.

Our programme would be to dig the dredge in from a point north of the Montrose Swing Bridge over the Welland River and have it excavate the earth from Sta. 10 to Sta. 56, thereby releasing shovels scheduled for this work for such intensive work in rock sections, that water can be turned into power house, Sept. 1st, 1921.

POSSIBILITY OF INCREASING THE CAPACITY OF THE CANAL.

The canal has three chief characteristics; First, the Welland River; Second, an Earth Section; Third, a Rock Section overburdened by the earth.

The Welland River section has a limitation of capacity of 20,000 c.f.s. near its mouth, but its present capacity can be increased up to such limitation of 22,000 c.f.s., as and when desired. The Earth Section, likewise, can also be increased up to 22,000 c.f.s. capacity as required, but the Rock Section when once excavated, lined and in use, cannot be so enlarged.

The Rock Section, however, lends itself in an economical manner to an increase in carrying capacity while still in its present incompleted state by simply deepening the rock cut without any further work on the over-burden of earth, bridges, etc. The river and earth sections can be enlarged with dredge as required at any future date, and immediate provision for the proposed increased capacity of 7,000 c.f.s. would only require the deepening of bottom of the rock section between Stations 45 and 450 about fifteen feet, requiring the excavation of 1,200,000 cu. yds. of additional rock and the placing of 75,000 cu. yds. of additional concrete lining.

The present and proposed plant with the Hydraulic Dredge Unit referred to in "Schedule to complete Sept. 1st, 1921," supplemented with an additional shovel unit and extra concrete plant, will make it possible for all the necessary work to be completed in the deepened rock section in time for power to be generated by Dec. 31st, 1921, at an additional cost of $4,900,000.00 for such additional rock excavation and concrete less $1,200,000,00 which would be recovered from the additional broken stone produced, or a net cost of $3,700.000.00.

A comparative estimate of the capital required for the various stages of the undertaking with rock section of the power canal deepened for the ultimate use of 22,000 c.f.s., is as follows:

Based on the present plans of five (5) Units for partial use of 15,000 c.f.s., will give 250,000 H.P. at an estimated cost of	$43,271,759.00
Estimated Net Cost to deepen Rock Section less receipts for broken stone	3,700,000.00
	$46,971,759.00

or Total Cost per H.P., 15,000 c.f.s. capacity.....	$173.08
Total Cost per H.P., 22,000 c.f.s. capacity.....	$187.89
The ultimate capacity of present plans contemplates the full use of 15,000 c.f.s., and the installation of a total of nine (9) Units, producing 450,000 H.P., and will require when installed, $9,000,000 additional capital, making a total estimated cost of.....	$52,271,759.00
Estimated Net Cost to deepen Rock Section less receipt from broken stone.....	$3,700,000.00
	$55,971,759.00
or Total Cost per H.P., 15,000 c.f.s. capacity.....	$116.16
Total Cost per H.P., 22,000 c.f.s. capacity.....	$124.38
Increasing the capacity of the canal as a whole to 22,000 c.f.s. and putting in operation a total of twelve (12) Units, producing 660,000 H.P., will add $11,900,000 to the above cost of Nine (9) Units, making a total estimated cost of.....	$67,871,759.00
or Total Cost per H.P.	$102.83

Comparison of cost per H.P. of various capacities until ultimate capacity of development is reached:

	15,000 c.f.s. Total Cap. 450,000 H.P.	22,000 c.f.s. Total Cap. 660,000 H.P.
250,000 H.P.	$173.08 per H.P.	$187.89 per H.P.
450,000 H.P.	116.16 per H.P.	124.38 per H.P.
660,000 H.P.	.....	102.82 per H.P.

In general we wish to advise you: first, that while this is a large undertaking it is in excellent shape for early completion; second, that all unknown conditions and uncertainties of construction have been eliminated; third, that the equipment is suitable; fourth, that we think that the peak of inefficiency of labour and the peak of prices of material and labour have been reached; and fifth, that with no unusual labour conditions, and with materials properly supplied, we consider the estimates of cost and dates of completion as feasible and dependable.

The project and its purposes appeal to us in all its phases. The conception and design is simple and effective and the construction work is being carried out with proper present day equipment and in an intelligent, capable way, with credit to all concerned.

Yours truly,
(Sgd.) Francis Lee Stuart.
(Sgd.) H. S. Kerbaugh.

H. S. KERBAUGH,
Room 817, City Investing Bldg.,
165 Broadway,

New York, Oct. 2nd, 1920.

Sir Adam Beck, Chairman,
Hydro-Electric Power Commission, Toronto, Canada.

Dear Sir:

In answer to your inquiry on the occasion of my recent visit to Niagara Falls, I may say that as a contractor I am willing to contract for the work

covered in the report submitted to you by Mr. Stuart and myself, at the unit prices mentioned therein. I would further undertake with the plant and recommended additional to that now on the work and on order to place the first two 55,000 H.P. units in operation on any of the specific dates mentioned in our report, which you might decide to elect.

Should your decision require the dredging unit referred to in the report submitted, I am willing to furnish the dredge and undertake the work for both the canal and river at the prices named in the report, and to finish within the time named.

Yours truly,
(Sgd.) H. S. KERBAUGH.

H. S. KERBAUGH,
Room 817, City Investing Bldg.,
165 Broadway,

New York, September 20, 1920.

SIR ADAM BECK, Chairman,
Hydro-Electric Power Commission, Toronto, Canada.

Dear Sir:—

Herewith enclosed please find a statement covering the most important construction work done by me during the period 1900 to 1920, which I trust will give you the record requested of my contracting experience.

Yours very truly,
(Sgd.) H. S. KERBAUGH.

H. S. KERBAUGH. September 20, 1920.

Record of the Most Important Construction Work done by H. S. KERBAUGH,

Contractor, from 1900 to 1920.

BALTIMORE AND OHIO R. R. COMPANY

SAND PATCH TUNNEL, for two tracks, through the Allegheny Mountains about 4500 feet long. Contract time, 17 months.

MAGNOLIA CUT-OFF IMPROVEMENT, for two tracks, including three tunnels and several million yards of very heavy rock work. Contract time, 15 months.

CURTIS BAY IMPROVEMENT, BALTIMORE, MD.: GRAVITY YARD, reinforced concrete pier including the piles and hydraulic dredge work, the material dredged being used for the gravity yard—about 500,000 cubic yards, which were pumped about 3500 feet and lifted about 36 feet. Contract time, about one year.

UNITED STATES GOVERNMENT.

BUFFALO, N.Y.—A very large amount of hydraulic and dipper dredge work, mostly in rock, covering a period of five years' work.

WAR WORK: Aeroplane spruce contract in extreme northwest corner of State of Washington on Pacific Coast. Fifty miles of very heavy main line construction work with two tunnels, completed ready for trains, and 125 miles of heavy branch line railroads, completed ready for track; lumber saw mill at Port Angeles electrically equipped with latest and most modern machinery, having the largest capacity of any mill on the Coast and requiring approximately 300,000 cubic yards of dredging for the preparation of mill site. Expenditure for the above work, about $12,000,000. Time, 4½ months. The contract provided for

a total expenditure of about $50,000,000 in 18 months, six months of which were for the above preparatory work, which was estimated at $15,000,000, and the aeroplane spruce product which was to have been delivered in the following twelve months was estimated at $35,000,000. The preparatory work programme was officially considered as being about six weeks ahead of schedule.

THE CITY OF NEW YORK—CATSKILL AQUEDUCT.

KENSICO DAM at Valhalla, N.Y. Officially stated to be the largest of masonry dams. Approximately 1,000,000 cubic yards of heavy cyclopean masonry, backed with large concrete blocks and faced with very heavy granite masonry. Contract time, 10 years. Completed in five years.

A part of the AQUEDUCT work for carrying water from the Catskill Mountains to and through the City of New York, about 18 feet in diameter.

These two contracts involved approximately $13,000,000.

STATE OF NEW YORK.

HIGHWAY WORK—300 miles of improved Telford and Macadam highways; constructed during two seasons.

ERIE BARGE CANAL—contracts, including terminals for same, covering a period of five years' work.

CITY OF HARRISBURG.

BRIDGE—Stone arch highway bridge across the Susquehanna River at Harrisburg, about 3,000 feet long.

GRAND TRUNK PACIFIC RY. CO.

RAILROAD—General heavy railroad work for change of line, etc.

PITTSBURG AND LAKE ERIE R. R. CO.

RAILROAD—General heavy railroad work for new line, near Pittsburg, Penn.

PHILA. AND READING RAILWAY COMPANY.

RAILROAD--General heavy railroad work for New York cut-off line.

PENNSYLVANIA RAILROAD CO.

Between New York, Washington, D.C., and Columbus, O.

BRIDGES—Two stone arch bridges over the Susquehanna River, one for two tracks and one for four tracks.

LOW GRADE FREIGHT LINE—for two tracks, along the Susquehanna River, south of Harrisburg, which involved the moving of about eight million cubic yards of rock, the building of the necessary bridges, the tracklaying, etc. Length, ten miles. Contract time, 15 months.

ENOLA GRAVITY AND CLASSIFICATION YARD—double tracking Northern Central Railway for forty miles; building new double track railroad for twelve miles. Work involved the moving of about 7,000,000 cubic yards of rock and 3,000,000 cubic yards of hard-pan; 300 miles of track and the ballasting of same, and the necessary masonry structures. Contract time, fourteen months.

BRILLIANT BRANCH—cut-off line at Pittsburg, for four tracks, which involved the moving of several million yards of rock excavation and the placing of about 200,000 cubic yards of masonry, covering a period of two years' work.

TRACK ELEVATION in and around Pittsburg and Allegheny. Principally heavy masonry work, track work and excavation for fills. Covering a period of about four years' work.

A very large GRAVITY AND CLASSIFICATION YARD south of Altoona, Penn., involving the moving of several million yards of excavation and the building of the necessary masonry structures; also track-laying, ballasting of tracks, etc.

FOUR TRACK ELEVATION through New Brunswick, N.J., including the building of stone arch bridge over the Raritan River and Canal; the building of stone arch masonry structures through New Brunswick, the required filling, track-laying, etc., covering a period of two years' work.

New two track FREIGHT LINE, including classification yards, track-laying, bridges, etc. (about twenty miles in length), between Gallitzin Tunnel, Summit and Holidaysburg, Penn. Contract time, one year.

ORGANIZATION AND EQUIPMENT.

PRE-WAR WORK—LARGEST SINGLE YEAR—Total force employed on two 10-hour shifts, about 12,000 men.

Plant in operation, 68 steam shovels, with the necessary complement of locomotives, cars, track, derricks, pumps, compressor plants, etc. Cost $3,500,000.

Excavation moved, principally rock, 13,000,000 cubic yards.

Masonry placed, about 450,000 cubic yards.

Track laid and ballasted, about 500 miles.

POLICY OF THE CONTRACTOR.

All work taken was done with his own forces.

Owned and operated his own stone quarries; his own ballast quarries; his own commissaries, and for contracts "A" and "B" manufactured his own dynamite on the site of the work.

Owned and operated his own machine shops (with large storage yard capable of storing his entire equipment if necessary, supply-house, etc.) located at Altoona, Penn., on the main line of the Pennsylvania Railroad, where all equipment was repaired and rebuilt and where all his dump cars were built. This shop was in addition to a repair shop installed on each large piece of work. The equipment and supplies required for a new piece of work were shipped out from the Altoona shops.

FRANCIS LEE STUART.
Consulting Engineer.
50 East 42nd Street.

Memorandum From Record of Francis Lee Stuart.

Mr. Stuart was born at Camden, S.C., December 3rd, 1866. Graduating from Emerson Institute of Washington, D.C., he gained his first engineering experience in 1884, as rodman on the Baltimore & Ohio R.R. Co. After several years on the Baltimore & Ohio R.R., and on railroads and coal mines in Alabama, he was appointed assistant engineer on the Nicaragua Canal Commission. As district engineer he had charge of a large part of the surveys made in Nicaragua for a canal, including a hydrographic survey of Lake Nicaragua. On his return to the United States he made the estimates of the several proposed canal variants.

Resigning from the Canal Commission in 1899, he again accepted a position on the Baltimore & Ohio R.R., and as engineer of surveys made the studies for grade line reduction over the system.

In 1905 Mr. Stuart was appointed Chief Engineer of the Erie Railroad Co., then contemplating a general scheme for reduction of grades and terminal arrangements. Entering on these studies Mr. Stuart was engaged for five years in an extensive programme of survey and construction work for the Erie System,

building some of the heaviest construction work that had been attempted in the Eastern part of the United States, including a scheme of bringing all the branch lines of the Erie into the Jersey City Terminal through a series of four track tunnels and open cuts, with an arrangement of flying junctions which precluded the necessity of trains crossing the tracks of opposing traffic at grade.

In 1910 Mr. Stuart was appointed Chief Engineer of the Baltimore & Ohio Railroad Co., and until 1915 had charge of the general grade reduction work and other improvements, which covered a large construction programme. Included in this expansion work was the construction of a coaling pier at Baltimore following a new scheme originated by himself, under which record rates for coaling vessels have been obtained. Mr. Stuart resigned from the Baltimore & Ohio Railroad Co. in 1915, to open an office as Consulting Engineer on various projects.

Upon our entrance into the War, Mr. Stuart was called to Washington, and as Chairman of the Terminal Port Facilities Committee of the Council of National Defense and of the War Industries Board, outlined a method for handling military supplies, by the War Department and recommended the location and programme installed at the Atlantic Ports, for the Army Bases, which were constructed. He was also a member of the Storage Committee, of the War Industries Board, and of the Depot Board of the War Department.

When the Government took over the Railroads of the United States he was selected Chairman of the Budget Committee and as such passed on all the plans and improvements of the Railroads east of Chicago and north of Norfolk, and made recommendation to the United States Railroad Administration as to whether or not the Government should permit and finance the improvements. Of the $851,000,000.00 authorized for Railroad improvements by the United States Railroad Administration Mr. Stuart passed on some $575,000,000.00 of works, etc.

He has a varied consulting practice in Port and Terminal work and in the Railroad and Industrial fields, and has invented and patented numerous machines and methods for handling materials, and is the originator and owner of the Stuart Systems of handling materials such as coals, ores, etc. The Baltimore and Ohio Railroad Pier at Curtis Bay, with a capacity for loading coal into vessels at the rate of four to six thousand tons per hour, was built from his designs and patents.

Mr. Stuart is Vice-President of the American Society of Civil Engineers, and Past President of the Society of Terminal Engineers.

REPORT of R. S. LEA, Consulting Engineer, on POWER CANAL OF QUEENSTON-CHIPPAWA POWER DEVELOPMENT, Oct. 26th, A. D. 1920.

R. S. & W. S. LEA
Consulting Engineers

New Birks Bldg.,
Phillips Square,
Montreal, Dec. 7th, 1920.

Sir Adam Beck, Chairman,
Hydro-Electric Power Commission of Ontario,
Toronto, Ontario.

Dear Sir Adam:

I hand you herewith revised copy in triplicate of my Report of Oct. 26th. 1920, on the Queenston-Chippawa power development.

So far as the opinions expressed are concerned, no change of importance has been made. Certain alterations and additions, however, have been made in view of more precise information on certain minor matters and with a view of bringing out a few points with greater prominence.

Yours very truly,

(Sgd.) R. S. Lea.

R. S. & W. S. LEA,
Consulting Engineers.

New Birks Building, Phillips Square,
MONTREAL,
October 26th, 1920.

Sir Adam Beck, Chairman,
Hydro-Electric Power Commission of Ontario, Toronto, Ont.

Sir:

On Sept. 14th last you wrote asking me to prepare a report for the Commission on the Queenston-Chippawa Development scheme, covering the following points:—

(A) A discussion of the water levels previously existing, and now and hereafter capable of being maintained on the Chippawa Grass Island Pool, as a basis for establishing the water carrying capacity of the power canal.

(B) A discussion and report on the design of intake proposed by the engineers of the Commission, having particular reference to the merits, if any, it may have as applied to the special conditions it is designed to meet, and as compared with other types of intake which you might consider are suitable, having due regard to efficiency and capital cost.

(C) An opinion based on your conclusions in regard to the above as to the water carrying capacity of the power canal as now designed.

I accordingly submit the following:—

(A) RIVER LEVEL AT CHIPPAWA GRASS ISLAND POOL.

The water levels previously existing at the Chippawa Grass Island Pool have been recorded semi-daily since 1902. The essential facts thereby established are that for the period covered by the records,

The mean level of the Pool was El. 560.5
The max. " " " " " " 563.0
The min. " " " " " " 558.5

The Standard Low Water Level for the Chippawa Grass Island Pool, adopted by the U.S. Lake Survey is El. 559.5. It is true that the Pool has temporarily dropped below this level, but such a contingency is somewhat rare, having occurred only thirty-one times during the past eighteen years; and on only eight of these occasions has it fallen below El. 559.0. In advance of Section (C) it may be here stated that the discharging capacities corresponding to these elevations are 15,500 and 15,100 second feet respectively. Moreover, Pool levels below 559.5 are always the result of an unusual combination of natural causes. They are therefore not only of rare occurrence but are necessarily of short duration, having never lasted longer than twenty-four hours at any one time, and have probably not averaged much over six or eight hours. In other words a Pool level of 559.5 or higher can be depended upon for all but about one-tenth of one per cent. of the time.

So far as the regular output of the Power plant is concerned, the result is still more favourable, for the reason that of the total number of times that there

is any deficiency in level, only about one-third occur in December and January, when the load is greatest; and even in these months account should be taken of the fact that they may happen during off-peak hours, or on Sundays or other days of light load.

In view of the considerations just referred to, it is my opinion that the dependable capacity of the Power Canal and the Chippawa-Queenston Hydro-Electric Power Development, in so far as they depend upon the Niagara River levels, can be very conservatively based on that stage of the river which under present conditions corresponds to El. 559.5 in the Chippawa Grass Island Pool.

The diversion of part of the flow of the Niagara River into the Chippawa-Queenston Canal would however tend to lower the water level in the Pool, unless compensated for in the river at or below the entrance to the canal. As will presently be referred to under Section (C), the quantity of water it is proposed to divert will be between 15,000 and 16,000 sec. feet, and even if no special nor incidental compensating works were provided at all, the diversion of this quantity of water would not lower the Pool, at the most, by more than five inches. As a matter of fact, however, the compensating effect of the Canal Intake structures as proposed, and of the adjacent and incidental work connected therewith, will be sufficient to offset any effect the proposed diversion tends to have in the way of lowering the level of the Grass Island Pool.

It should further be observed with regard to the permanence of the level of the Pool and the possibility of maintaining it, that if further diversions are permitted in the future, the natural conditions in the bed of the river below the Canal entrance lend themselves very favorably to the convenient and economical construction of whatever remedial works may be found necessary to maintain the present levels or to raise them to some extent if it should prove desirable to do so.

When, therefore, the dependable capacity of the Power Canal is dealt with under Section (C), it will be based on a river elevation of 559.5 at the Chippawa Grass Island Pool.

(B) INTAKE.

The design and construction of the necessary works at the entrance to the Power Canal presents no difficulties so far as summer conditions are concerned. In the winter season, however, the Niagara River at times carries considerable drift ice and frazil, against which all power plants in northern climates require protection.

In the Chippawa-Queenston scheme this feature is of more than ordinary importance on account of the great length of the power canal, approximating twelve miles, and the magnitude of the development. The extent to which the ice can be eliminated from the water diverted into the canal will be the measure of the success of the design and construction of the Intake Works. The problem is not an easy one, and it has never been completely solved under similar conditions in connection with works of the extent proposed in this development. In the absence of successful precedents, exhaustive tests have therefore been carried out over a period of two years by Prof. Angus of Toronto University under the direction of the Commission's engineers, all of whom have had many years' experience in connection with the construction and operation of hydro-electric developments at Niagara Falls.

These experiments were conducted on a larger scale than any previously attempted in connection with hydraulic work of this kind. A section of the Niagara River channel embracing the entrance to the Welland River, and extending for a

long distance up and down stream, was constructed on a scale of 1 to 20. Experiments were made with different kinds of intakes, as a result of which a certain type was evolved which indicated marked superiority over the others as a means of preventing ice from being carried into the canal. A special series of tests of this type were carried out under the general direction of Mr. R. D. Johnson, Consulting Engineer, of New York, who subsequently worked out the design which has finally been adopted.

Without referring to details with which you are familiar, the canal entrance works as designed may be described as forming two intakes which are quite separate in their action and which may be operated either independently or in combination. One of these is a surface intake of the so-called fixed or permanent boom type, constructed throughout of concrete and provided with fifteen openings 18' wide and 28' deep below the curtain wall, all controlled by gates operated from an upper platform or deck. This structure, including the navigation lock which is incorporated with it, will extend out into the river for a distance of about 700' in a direction slanting down stream. It represents the simplest and best method for the control and admission of water into the power canal except at such times as the ice conditions are troublesome; and since it is of paramount importance to insure continuity in the operation of such a large plant, the second intake has been specially designed for ice protection.

It is entirely submerged, and consists of six parallel concrete tubes, 100 feet on centres and 600 feet in length, which extend out diagonally into the river, in an upstream direction, from the boom type intake referred to above. These tubes will be built on rock, which occurs here at about 16 feet below the river bottom. They will be set at such a depth that the top of the tubes will be at the same elevation as the original river bed. They are horseshoe-shaped in cross section, with an inside diameter of about 20 feet for the greater part of their length, terminating in a tapering section at the outer end. They enter the canal through the surface intake and between its openings, at which point they are provided with control gates and expanding mouthpieces. For the first hundred feet from the control gate the wall of the tube is continuous, but beyond this and extending to the outer end there is a longitudinal opening or slot of varying width, located a little below the top and provided with guide vanes to properly direct the entering water. A most important and unique feature is that the tubes and inlets are so designed that the inflow of water will take place at a pre-determined rate per foot of length of tube.

In addition to the excavation necessary to set the tubes at the proper elevation, the earth overlying the rock will be removed on the upstream side of each tube. In the case of the tube furthest up this trench will have a width of 100 feet.

The special form of intake just described will have several advantages over any so far devised for excluding ice from the canal. In the first place, on account of its submergence, it is free from one of the principal objections to the boom type of intake, which of necessity forms a surface obstruction against which the floating ice tends to accumulate and be drawn under by the down draft of the inflowing water. In the second place, and for the same reason, the inlets are as far removed as possible from the surface water where most of the ice is carried which is likely to give trouble in connection with the operation of the canal. In the third place, the openings are distributed over such a considerable area of the bottom of the river that the water will enter the tubes with minimum disturbance of the flowing stream. Moreover it is the only intake yet proposed in which the rate of inflow at every point can be effectively and positively controlled.

Usually only the surface intake will be in service and the loss of head at the entrance to the canal will be of little importance. It is estimated, however, that when the gates of this intake are closed, and a draft of 15,000 sec. ft. is drawn entirely through the submerged intake, the loss of head will be somewhat less than six inches. This condition will prevail for only a comparatively small proportion of the total time, but in estimating the dependable carrying capacity of the power canal, the loss at the canal entrance has been based on the assumption that only the second intake is in service.

The cost of the entire structure will be at least twice that of the ordinary fixed boom type of intake of equal stability and with as effective provision for the requirements of navigation. The total estimate as prepared by your engineers is a little less than $3,000,000.00. In the initial installation, however, it is intended to build only part of the submerged intake, terminating the tubes about 100′ from the control gates. This will reduce the estimates for immediate expenditure in connection with the intakes to $2,000,000.00. When the draft of the power canal increases to such an extent as to require it, the second intake will be carried to completion.

Experience on the St. Lawrence and other rivers in Canada has demonstrated that the difficulties of dealing with ice are much greater in the case of a long canal or head race than where the supply is directly to the power house. Hence every care should be taken, as has been done here, to ascertain the form of intake which will provide the best possible protection against the entrance of ice under the conditions which exist in the river in the vicinity of the intake; and, as the canal is the sole channel of supply to the entire power plant, the effectiveness of this protection becomes of still greater importance, and a relatively high first cost is fully warranted. I am therefore of the opinion that the expenditure involved in the construction of the Chippawa intake as proposed, is justifiable on the grounds just mentioned, in view of the additional security which this particular type of intake will afford against serious troubles from ice entering the canal.

(C). CARRYING CAPACITY OF THE POWER CANAL.

After having observed the character of the work of lining the rock section, and having given due consideration to other points which have an important bearing on the matter, I am of the opinion that conservative values have been adopted by your engineers for the hydraulic co-efficients, which are the controlling factors in determining the discharging capacity of the canal. I am therefore in agreement with their estimates in this regard.

The dependable capacity so far as power is concerned, can, as stated previously, be based on a river level at Chippawa of 559.5. With this elevation, and assuming a loss of head in the intake of six inches, the calculated capacity of the canal, as now designed, is about 15,500 second feet. With a river level of 559.0, and a similar intake loss, the capacity would be about 400 second feet less.

In view of what has just been stated, and of the fact that provision is to be made for keeping the canal open in the reaches of low velocity, where an ice cover may tend at times to form, I am of the opinion that the dependable capacity for power purposes may safely be taken at not less than 15,000 cubic feet per second.

Yours very truly,

(Sgd.) R. S. Lea.

Sir Adam Beck, Chairman,
Hydro-Electric Power Commission,
Toronto, Ontario.

This is in acknowledgment of and in reply to your letter of October 6th making inquiry as to our judgment in respect of the lowering of the water in the the Grass Island-Chippawa Pool by diversions from the Niagara River.

This matter is one that we consider of vital importance, and we are much concerned lest there be a lowering of the water level in this pool.

The Niagara Falls Power Company and its constituent companies have, for over twenty years and at the expense of millions of dollars, based their intake work, waterways and power stations upon the levels for this pool in the natural flow of the river established by the U.S. Lake Survey, which has given elevations as indicated below:

	Lake Erie	Grass Island Guage
1. Mean Water Level	572.58	562.06
2. Standard Low Water	570.0	560.6

It is, therefore, apparent that any diversion that would change these levels must be viewed by us as detrimental to our interests, and it is our judgment that 560.6 (U.S. Lake Survey datum) as measured on the Grass Island guage, is the lowest level of this pool under which we can safely and continuously divert the water allowed by the treaty for power purposes upon the American side above the Falls.

Our engineers also advise that there is a difference of approximately 1.7 feet between the U.S. Lake Survey datum and that used by the Hydro-Electric Power Commission; also that there is now a difference of level in the Grass Island-Chippawa Pool, the Chippawa side being approximately 0.6 feet higher than the Grass Island side. Therefore, correcting for these factors, the elevation of 560.6 (U.S. Lake Survey datum) on this side of the river would correpond to approximately 559.5 at Chippawa (Hydro-Electric Power Commission datum).

We, of course, appreciate that natural conditions, such as wind and ice, will, from time to time, impose a condition of low water upon the Niagara River which will temporarily lower even the standard low water levels above mentioned.

In regard to what recourse or remedy should be applied for the maintenance of the above levels in case of their being lowered by diversion, we believe it should take the form of such remedial works as would meet the approval of the respective governments, and also of the power developing interests which have based their works upon the above established levels. This would be in accord with the procedure previously agreed upon in the matter of disposing of excavated material from our respective intake works in such portion of the Chippawa-Grass Island pool as will most effectively compensate for any lowering of the natural levels.

Yours very truly,
(Sgd.) Paul A. Schoellkopf.

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